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New York University
Constant Level Balloons
Section 2, *Operations*
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CONSTANT LEVEL BALLOONS
Section 2

OPERATIONS

Constant Level Balloon Project
New York University

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New York 53, New York

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I. INTRODUCTION

A. Purpose of Manual

This manual is designed to serve as a guide in the preparation, launching, and tracking operations of constant-level balloons. In the body of this manual, most of the discussion applies specifically to the 20-foot diameter balloon developed by General Mills, Inc. In Section IX, a brief description is given of the other sizes of balloons used for constant-level flight. The manual is based upon the experiences and investigations of the Constant Level Balloon Project, Research Division of the College of Engineering, New York University. The charts and tables which were developed to use for this work are included in Appendix II of the manual.

B. Principles of Altitude Control

For constant-level work, non-extensible balloons are used for three reasons:

(1) With a given weight of equipment, it is possible to determine before the release of the balloon, the maximum altitude which will be attained.

(2) Without special control equipment, it is possible to maintain a nearly constant altitude for periods from one to six hours, depending upon atmospheric conditions and floating level. Generally, it is not possible to extend such flights through a sunset.

(3) By adding altitude control equipment, it is possible to maintain the balloon at various nearly constant, predetermined levels for periods of much more than six hours regardless of the time of day.

II. GENERAL MILLS 20-FOOT BALLOONS

A. Description

General Mills, Inc. of Minneapolis, Minnesota, has developed a series of non-extensible, plastic balloons. These balloons are tear-drop in shape, made from extruded polyethylene sheet, 0.001" thick. Cells are currently produced with a diameter of 7, 20, 30 and 70 feet. The

volume of the 20-foot cell is about 4300 cubic feet and its uninflated length is 38 feet. It is made up of 20 gores, heat sealed together in a butt weld. Along the seams thus formed, a special acetate-fiber scotch type tape (Minnesota Mining and Mfg. Co.,) is laid to reinforce the weld and to carry and distribute the load. These tapes converge to an appendix ring at the balloon bottom, to which the load harness is attached. By using this stressed tape design, much larger loads may be carried than the thin polyethylene alone could hold. To exclude air entering through the bottom, which is left open, an external skirt or appendix is added.

Figure 1 shows a 20-foot balloon ready to be released, with an external appendix in position. As the balloon rises, the lifting gas inside will expand until the balloon is full, whereupon the excess gas which was needed to make the balloon rise will be valved out. The full balloon will then float at a level where the buoyancy just balances the load. It will remain there until buoyancy is lost by diffusion of the lifting gas, or by cooling, as at sunset.

Neglecting minor effects, the amount of gas which is needed to just balance the load at the maximum or floating elevation would also just balance the load at any lower level, including the surface, although the balloon would be less than completely full at such a lower level.

B. Load Limits

For a given lifting gas, the altitude to which a balloon will rise is determined principally by the load it bears. With a 20-foot General Mills balloon, using helium, a payload of 40 pounds will reach approximately 46,000 feet and an 18-pound load will go to about 58,000 feet. Although the manufacturers recommend keeping the payload between 18 and 40 pounds, no trouble has been found in launching loads of as much as 70 pounds (37,000 feet) or as small as 4 pounds (67,000 feet).

C. Appendices

For highest altitudes and smallest sunset effects on a balloon, it is necessary to keep air from diluting the helium. To accomplish this, a check valve is required in order that helium may be valved when the balloon is full, yet air not be permitted to enter at any time. An appendix, consisting of a tube of balloon material, whose length is about 2 to $2\frac{1}{2}$ times its diameter is used for this purpose, and is supplied as part of the General Mills balloon.
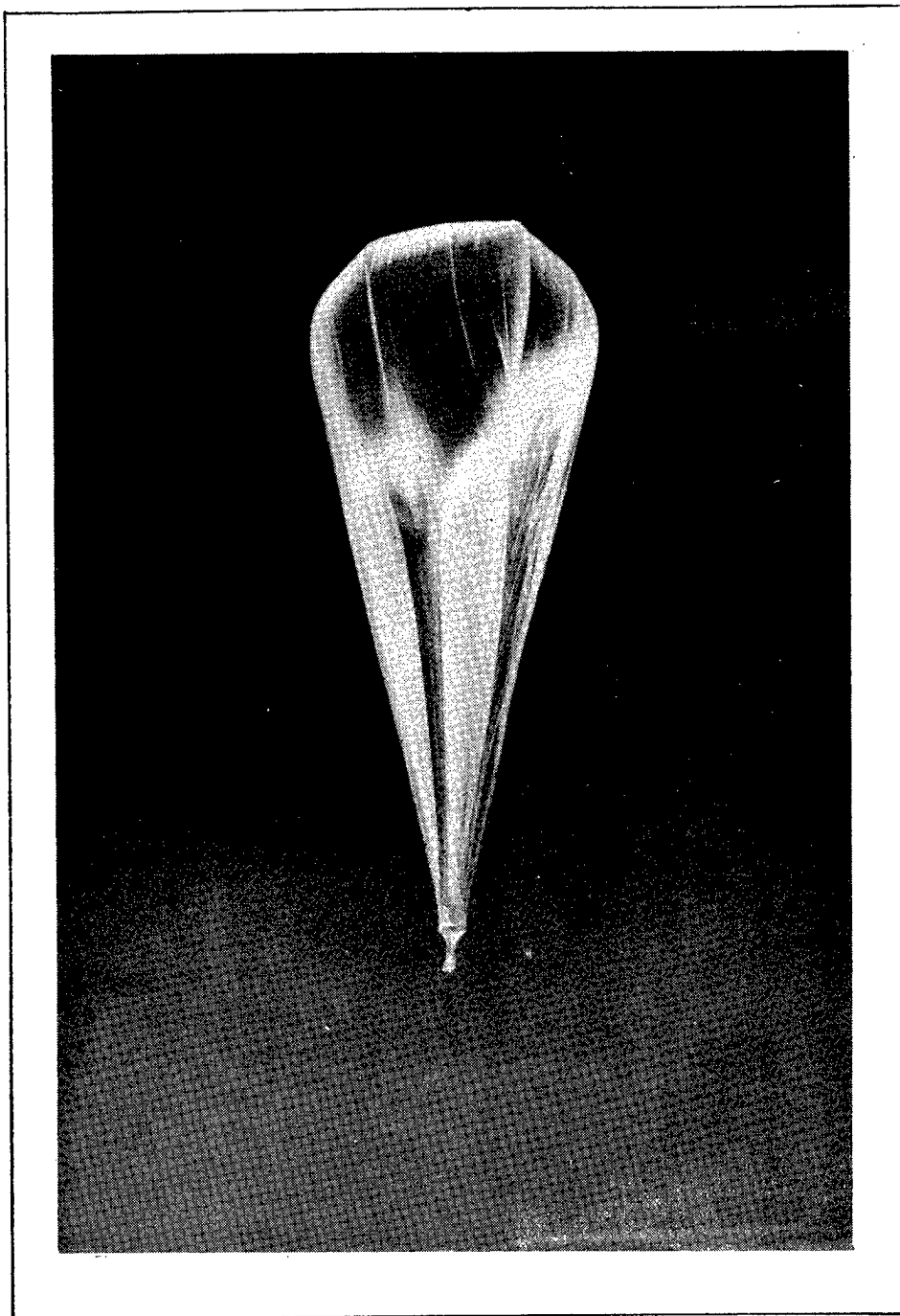
Figure 1
General Mills 20 foot balloon in flight with 2
foot appendix, stiffened with cardboard battens.

Stiffeners are added so that the appendix will not foul in the rigging. With a fouled appendix the helium cannot be valved, and the balloon after becoming full at its ceiling will burst. These stiffeners are taped to the outside of the appendix just before inflation.

The various appendix types which have been used are given in the following table:

Appendix Data

Appendix Type	Stiffeners	Effect on Altitude Attained	Effect on Descent
None	None	Ceiling is 10,000 to 20,000 feet lower than computed.	Balloon remains full at all times after ceiling is reached by taking on air. Greatly complicates control.
Standard	3 corrugated cardboard battens, $2\frac{1}{2}''$ by 15"	Computed ceilings attained.	Balloon remains full at all times after ceiling is reached by taking on air. Greatly complicates control.
Standard	4 aluminum battens 15 x $\frac{1}{2}$ x .030" 24 ST	Computed ceiling attained if balloon does not burst due to restriction on appendix.	Air excluded during any descent fairly well.
Flattened Tube	Metal spring bow to hold appendix flat, like pressed trousers	Not yet flight tested. Similitude tests indicate computed ceiling would be reached with no bursts due to appendix at 1000 ft/min rate of rise.	Not yet flight tested. Similitude tests indicate almost complete exclusion of air.

Figures 2, 3, and 4 show the various appendices described in the above table.

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Figure 2

Two foot appendix, stiffened with card-
board battens, shown on a General Mills
balloon. The swollen inflation tube
indicates that the balloon is being filled.

Fig. 3

Approx. 13 In.

Taped Edges
(Mystik Tape)

5/8"
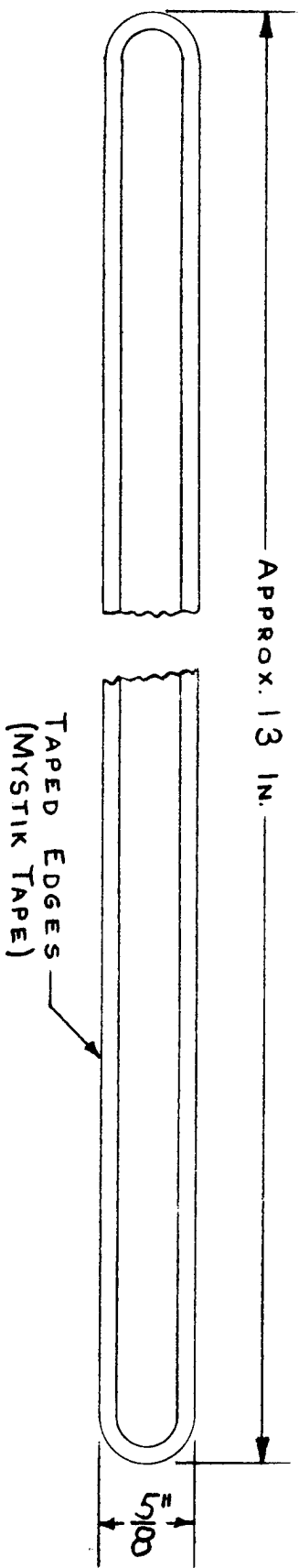
NOTE:

MAT'L: 17ST OR 24ST AL. SHEET-.032 THK.
ALL EDGES TO BE COVERED WITH TAPE
3 BATTENS, 120° APART
BENT IN FIELD TO FORM LIGHT
CLOSURE OF APPENDIX
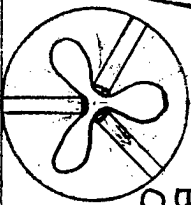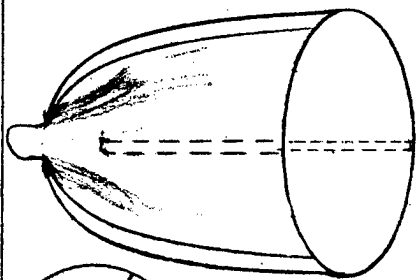
BATTENS FOR G.M.
20 FT. BALLOON

DWN: LHM
DATE: 10-14-48

ED48-95A

Figure 4
Two foot appendix, showing
metal spring bow in position.

Since the back pressure forcing the helium out of a
full balloon when it is rising is 4 times as great at
1000 feet per minute as at 500 feet per minute, the rate
of rise is critical when an appendix is used. It has
been found necessary to limit the rate of rise to 700
feet per minute to prevent bursting at ceiling when using
General Mills 20-foot balloons with standard appendix.
It is believed, from laboratory tests, that use of the
spring bow stiffeners on the new appendix will permit rates
of rise up to 1000 feet per minute. Flutter in the bal-
loon fabric while rising is apt to cause failure due to
ripping at speeds of more than 1000 feet per minute. A
20-foot General Mills balloon will burst with an internal
pressure of 0.014 psi., which is about 1 mb., equivalent
to a 200-foot rise at ceiling with a closed appendix.

III. EQUIPMENT TRAIN

A. Lines and Rigging

Following rigging failures early in the testing program,
careful study was given to the lines and rigging methods
used to attach flight instruments to the balloon. For
safety in launching, a factor of 10 to 1 is used on all
loads. Thus, if a 40-pound load is to be lifted, it is
not safe to use less than a 400-pound tested line. The
line strength should be determined independently if
possible, since the actual breaking point of lines runs
between 50 and 70% of the manufacturer's rated strength.

Braided or woven nylon is recommended for all rigging.
A stranded or laid line is subject to untwisting in flight,
twirling the suspended instruments and reducing line
strength. The nylon material is weather resistant to a
high degree and tends to stretch under shock rather than to
snap. For some purposes it may be desirable to use a line
of constant length, in which case the nylon may be pre-
stretched. Only a few of the common knots are useful
in tying nylon. Bowlines and square knots have been found
to slip and are hard to untie. The carrick bend, shown
in Figure 5, is recommended. In addition to this, a safety
knot is made in the loose end, and the entire tie secured
by a final taping. For convenience in assembly, the indivi-
dual pieces of line and equipment are rigged with harness
snaps at each end. This permits unit replacements or re-
moval at the last minute with a minimum of delay. For
extremely light-weight rigging, wooden toggles and loops
in the nylon may be used instead of the heavier metal
snaps.
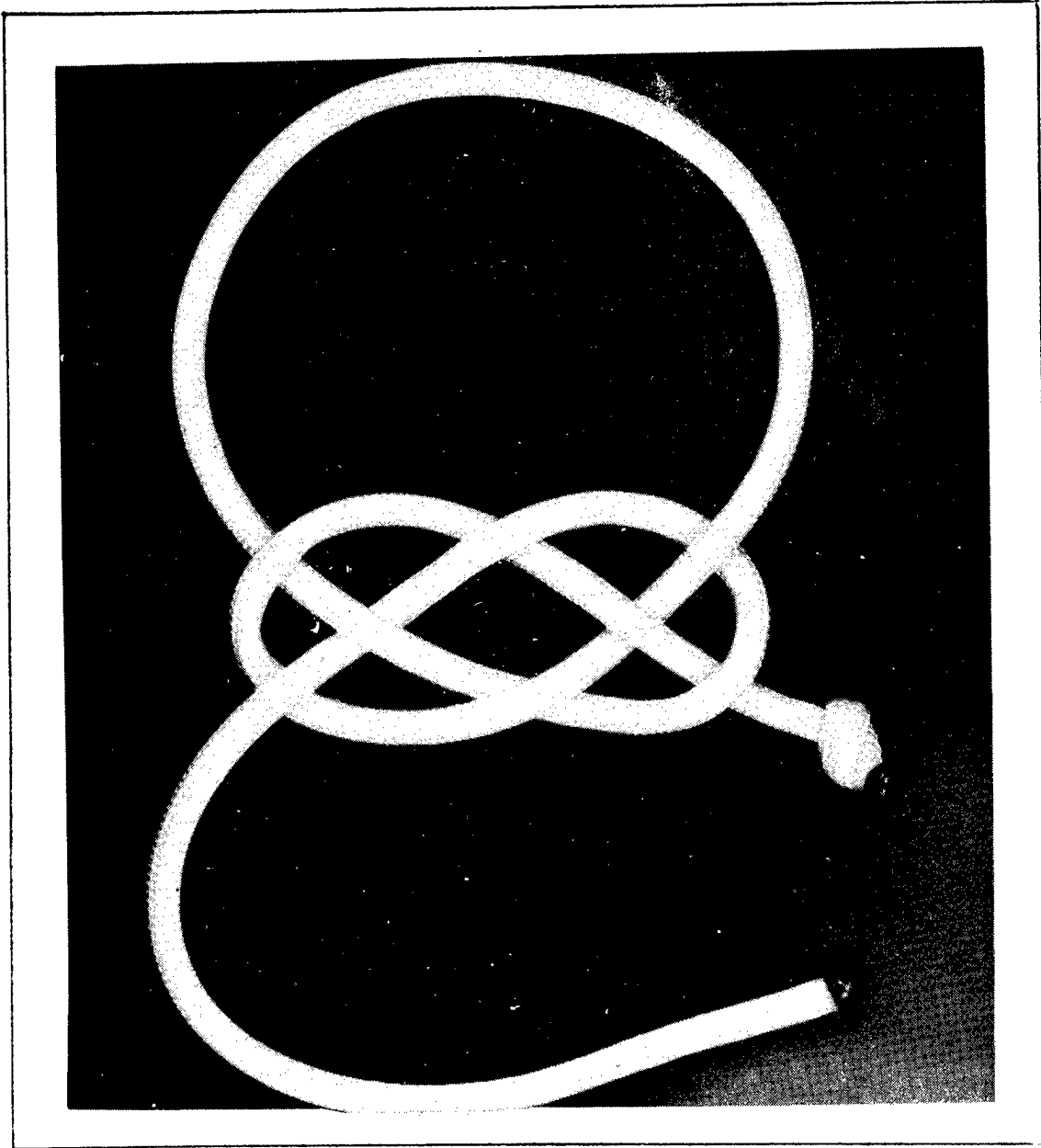
Figure 5

Carrick   Bend

B. Altitude Control Equipment

Flights of 20-foot General Mills balloons, using no control equipment, have been sent to altitudes of about 50,000 feet. After reaching maximum altitude, the balloons all exhibit a tendency to float then descend at an increasing rate for periods of from 2 to 6 hours. In stable layers of air such as the stratosphere the descent of a balloon is retarded by the helium, on compression, getting warmer than the surrounding air. This results in much longer duration flights requiring no external control though, strictly speaking, the altitude is not constant. This concept is in good general agreement with the observed data; balloons have remained in a semi-floating state much longer (up to 30 hours) when in the stratospheric inversion than when in less stable lower atmospheric layers.

When it is desired to maintain a balloon at constant level for a guaranteed period of time in excess of two hours, a ballast system of altitude control should be added to the flight gear. The level at which the balloon is to float must be the maximum altitude to which it can carry the payload. To compensate for loss in buoyancy occasioned by loss of lifting gas through diffusion and leakage, a continual lightening of the load is required. To effect this in a simple fashion, liquid ballast is permittted to flow through an orifice at a predetermined rate which exceeds the expected loss of lift. (See Section IV, D) The reservoir and ballast assembly which has been developed for this use is shown in Figure 6. A detail sketch of the orifice in its mounting is shown as Figure 7, and Figure 8 shows a suitable filter which must be used to protect the orifice from clogging. The liquid ballast must (1) not freeze, but flow well at cold temperature (-80°C); (2) not absorb water, which would freeze; and (3) be relatively inexpensive. A recommended liquid is Aeromobil Compass Fluid, made by Socony-Vacuum Co. (Air Force Spec. AN-C-116).

There are three possible objections to the use of this simple control system. First, a continued lessening of the total weight on the balloon--with no change in volume-- must result in a constantly rising ceiling. For a 20- foot balloon at 45,000 feet, this change is approximately 1000 feet with each kilogram of ballast dropped (see Section IV, E). Second, only a prefixed ballast flow is permitted, and excessive loss of lift, as might come when the gas is colled at sunset (when the balloon loses superheat),

SMALL HOOK

ONE GAL. CAN WITH $\frac{1}{2}$" FILLER HOLE

$6\frac{1}{2}$" DIA.

6"

$\frac{5}{8}$" DIA. BRASS RING SILVER SOLDERED

$\frac{3}{16}$" BRASS TUBING .032 WALL.

TWO BRACES - $\frac{1}{8}$" BRASS TUBING - EQUALLY SPACED

21"

MIN. HEAD - 18"

NOTE:
ALL JOINTS SILVER SOLDERED.
USE 3" CONE TYPE FILTER WITH 325 × 325 WIRE CLOTH ORIFICE ATTACHED WITH $\frac{1}{2}$" I.D. TYGON SEE ED48-75 ORIFICE & FILTER NOT ASSEMBLED ON RESERVOIR UNTIL READY FOR FLIGHT

25"

FILTER SUPPORT ARM - 5" LONG $\frac{1}{8}$" BRASS TUBE WIRED TO FILTER WITH N° 20 B&S GAGE SOFT BRASS WIRE

SPINNERETTE ORIFICE INSERTED HERE.

$\frac{1}{2}$" TUBING - 1" LONG
$\frac{3}{16}$" TUBING - 1" LONG
$\frac{3}{16}$" I.D. TYGON - $1\frac{1}{4}$" LONG

FIG. 6

4"

$\frac{1}{2}$"

$1\frac{1}{2}$" R.

RATE OF FLOW 200 TO 250 GM./HR. WITH .008" SPINNERETTE.
WEIGHT APPROX. 575 GM. COMPLETE LESS BALLAST.
CAPACITY - APPROX. 2800 GM. OF BALLAST

NYU BALLOON PROJECT

1 GAL. CAP. LT WGT. FIXED RATE BALLAST RESERVOIR

DWN BY: LHM
DATE: 9-2-48

ED48-79A

MONEL OR NICKEL
SPINNERETTE ORIFICE
SOFT SOLDERED
½" BRASS TUBE

SPINNERETTE ORIFICE

½"

ATTACHED WITH WIRE

TYGON TUBING

PLUG

DISCHARGE PLUGGED
UNTIL READY FOR FLIGHT

TO BALLAST RESERVOIR

NOTE:
SPINNERETTE ORIFICE MFD. BY J. BISHOP
CO., MALVERN, PA.

FIG. 7

NYU BALLOON PROJECT

ORIFICE ASSEMBLY

DATE	
8-25-48	ED48-75A

JN

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SECTION A-A

SOFT SOLDERED

BRASS CONE

0.025"

SILVER SOLDERED

WIRE MESH 325×325
(PHOSPHER BRONZE)

$\frac{1}{4}$"

30°

$\frac{5}{8}$"

$3\frac{1}{4}$"

$\frac{3}{4}$"

BRASS TUBING
$\frac{1}{2}$" OR $\frac{3}{16}$" O.D.
CUT $1\frac{1}{8}$" AND
FLARE ONE END

SCALE 1:1

3"

A

A

FIG. 8

NYU BALLOON PROJECT
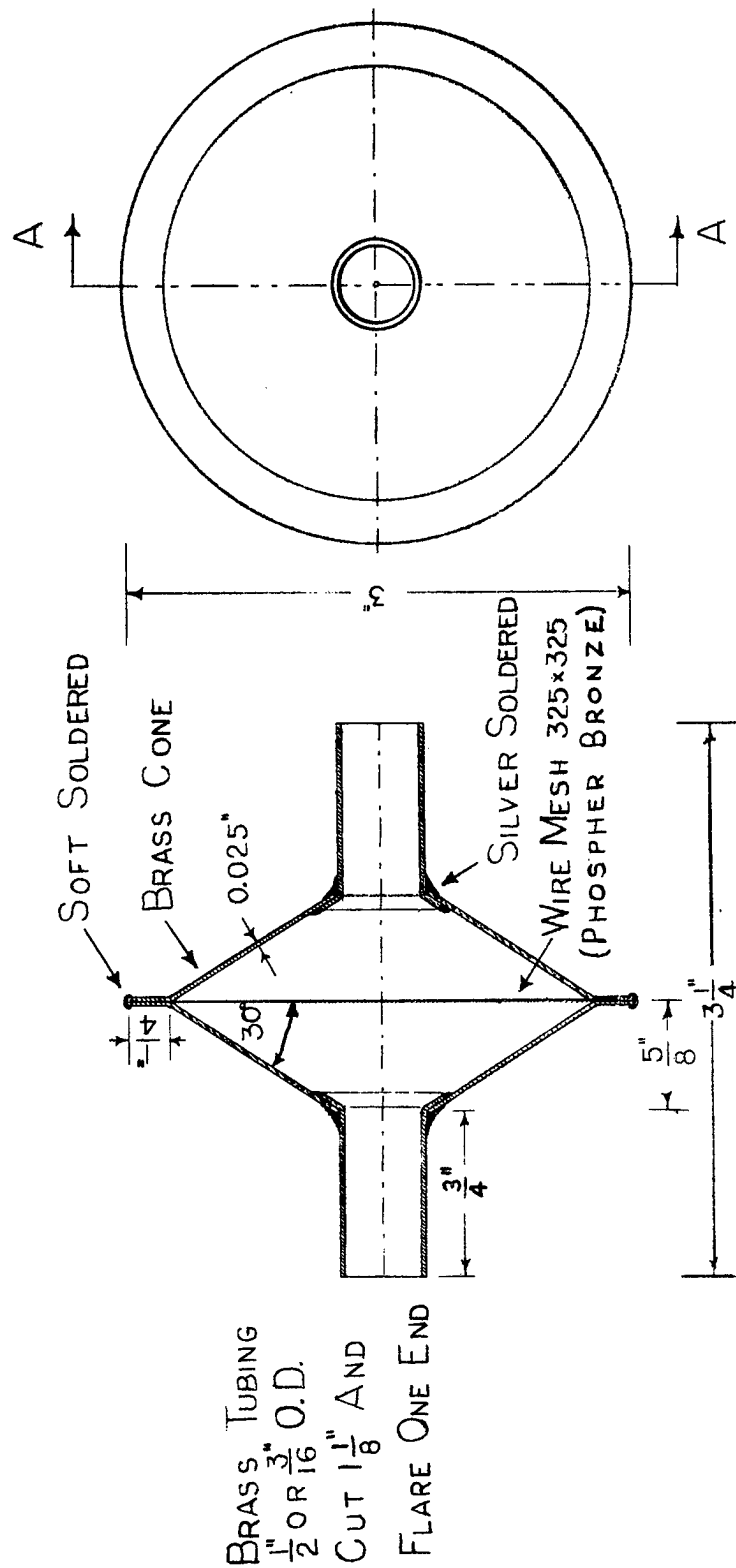
TYPE "C" FILTER

Date: 5-18-48   ED 48-54A

NOTE:
WIRE MESH FROM NEWARK WIRE CLOTH
CO., TWILLED WEAVE CODE PYA, OR
EQUIVALENT,

will cause the balloon to descend. Third, as a consequence
of the previous limitation, the maximum floating period
of a balloon with this control system is 24 hours, achieved
when launching is at sunset.

When any or all of the above objections prohibit the
use of this simple control system, more complex ballast
dropping devices may be used. Figure 9 shows in schematic
form the servo or demand type control which has been used
to maintain balloons at a constant pressure level, with
high ballast efficiency and without harmful sunset effects.
Figure 10 is the ballast reservoir assembly which is used
with this type control. A more detailed discussion of
this servo-control is given in Techncial Report Number 2
of the Balloon Project, New York University.

C. Flight Termination Gear

When a balloon loses buoyancy by the loss of lifting gas,
it sinks slowly to earth. To prevent the balloon from
remaining in airplane traffic lanes for a long period
of time, a flight termination device is added to the
equipment train. This device, shown in Figure 11, con-
sists of a pressure-actuated switch and rigging to tear
a large hole in the balloon when it descends to some
predetermined height. A pressure pen is held above
its commutator by a short shelf (see Figure 12). After
passing an altitude corresponding to the end of the shelf,
the pen falls onto the commutator. Upon subsequent
descent to 20,000 feet, it closes an electrical circuit.
When this circuit is closed, a squib is detonated in an
aluminum "cannon" (see Figures 13 and 14) driving a pellet
through the main load line. As the line is severed,
the weight of the load is suddenly taken by a rip line
which extends nearly taut (about 2 feet slack) up the
side of the balloon to a point about 10 feet below the
balloon crown. At this point, two small holes about
18" apart have been made, and the rip line is passed from
the outside into the balloon through the top hole, then
down the inside and out the bottom hole. Both holes are
securely taped with acetate fiber tape. About 6 inches
of slack line is left inside the balloon. When the main
line is cut, a large hole is made in the fabric by this
rip line as it pulls out of the balloon. After the in-
struments have fallen about 10 feet and the rip is made,
they are caught up by a snub line and the load is again
taken to the load ring. The ruptured balloon then acts
as a parachute for the load, descending at about 1000
to 1500 feet per minute.

HIGH ALTITUDE CONTACT

ANEROID BELLOWS

COMMUTATOR

DISPLACEMENT SWITCH

SOLENOID VALVE

SIGMA RELAY

RATE SWITCH

6V

6V

FIG. 9
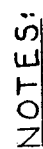
BALLAST CONTROL
CIRCUIT
LHM
11-12-48 ED48-114 B

NOTES:
BATT. PACK IN TRANSMITTER BOX
SIGMA SENSITIVE TYPE 5F RELAY-COIL
RESISTANCE-16000 OHMS
DISPLACEMENT SWITCH-ED48-107
RATE SWITCH-ED48-115
SOLENOID VALVE-ED48-110
USE 4FH-6V LITHIUM CHLORIDE BATTERIES (BURGESS)
FOR DETAILS OF DISPLACEMENT SW. SEE ED48-126
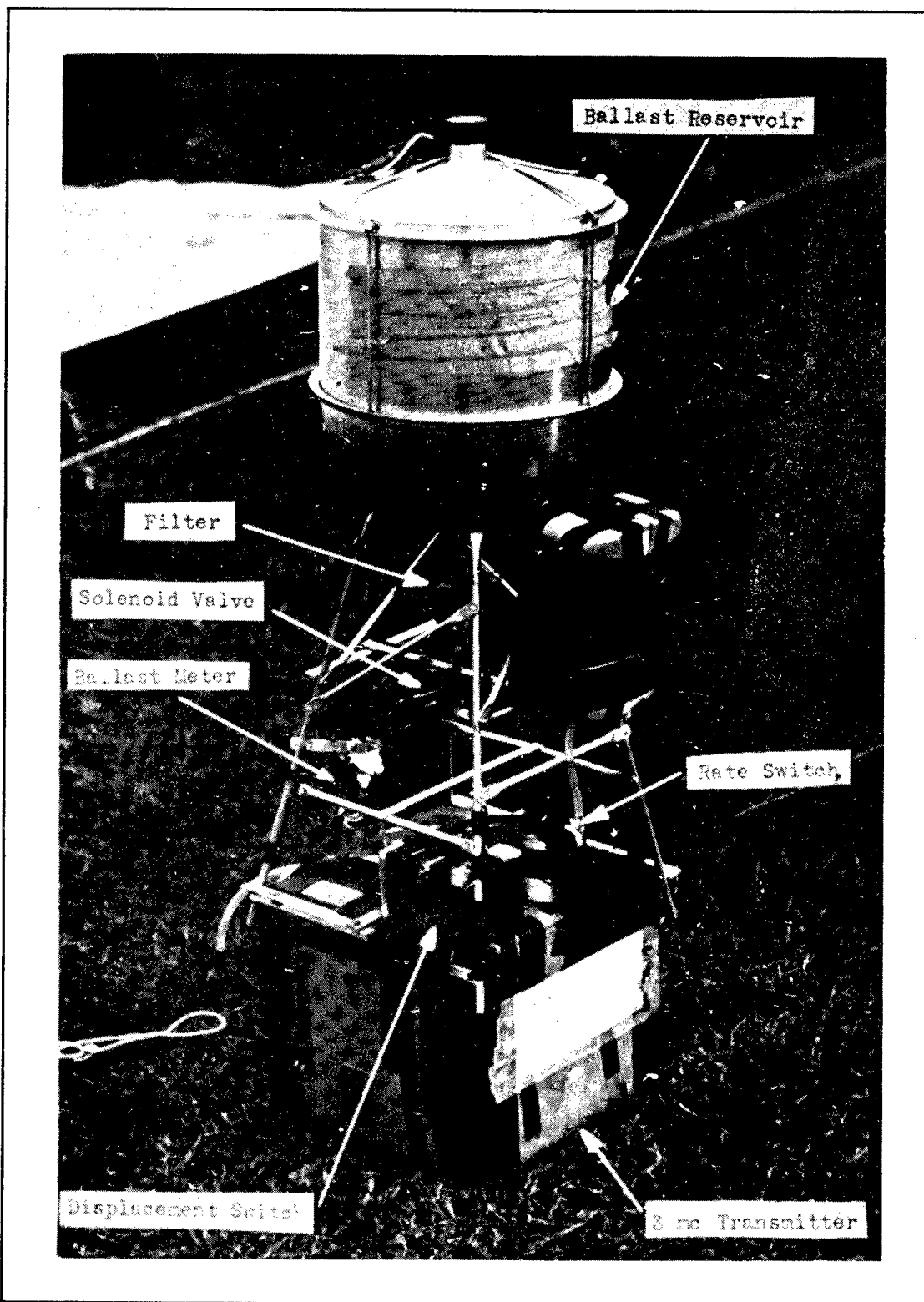
Figure 10

Ballast reservoir assembly
showing component parts

KNOTS ABOVE
AND BELOW CANNONS

34' RIP LINE
OF 100# TEST
BRAIDED NYLON
WITH 2' SLACK

APPENDIX

3' LINE

2 SQUIB FIRING CANNONS TO BE
FIRED AT 20,000 FT BY
FLIGHT TERMINATION SWITCH

10' SNUB LINE (COILED UP) TO TAKE
PLACE OF 1 FT LINE, WHICH HAS
BEEN CUT (BOUND WITH THD)

FLIGHT TERMINATION SWITCH RIPS
BALLOON ON FINAL DESCENT TO
20,000 FT, THUS REDUCING
FLOATING TIME IN THE AIR LANES.
THE HALF DEFLATED BALLOON THEN
ACTS AS ITS OWN PARACHUTE

ACETATE
FIBER
TAPE

1'

RIP LINE (100# TEST
OR LOBSTER TWINE)

6" SLACK
INSIDE BALLOON

KNOT

BALLOON WALL

DETAIL OF RIP LINE
INSERT INTO BALLOON

FIG. 11

NYU BALLOON PROJECT

FLIGHT TERMINATION RIP RIGGING

| DATE 7-19-48 | ED 48-68A |

JN

-23-

PEN ARM IS ON SHELF UNTIL BALLOON RISES ABOVE 25,000 FT. WHERE IT FALLS ON TO THE COMMUTATOR. WHEN THE BALLOON DESCENDS THE PEN ARM RIDES DOWN ON COMMUTATOR UNDER THE SHELF, CLOSING THE CIRCUIT AT 20,000 FT.

NOTE: MFD BY KOLLSMAN

Nº2 SHAKE PROOF LOCK WASHERS UNDER TOP AND BOTTOM NUTS

COMMUTATOR OPEN ABOVE 45TH CONTACT

COMMUTATOR OPEN ABOVE 45TH CONTACT

SHELF DETAIL

7/8"

1/4"

1/4"

1 1/16"

2-56 NF

SILVER SOLDER

3/32" BRASS WIRE

PEN ARM SHELF

PEN ARM

ANEROID CELL

12" WIRE LEADS – 20 GAGE STRANDED WIRE

LINKAGE DETAIL

BRACKET HOLDS PEN ARM CAPTIVE

CIRCUIT CLOSES ON DESCENT TO 20000' STANDARD ATMOSPHERE

TO SQUIB CANNON
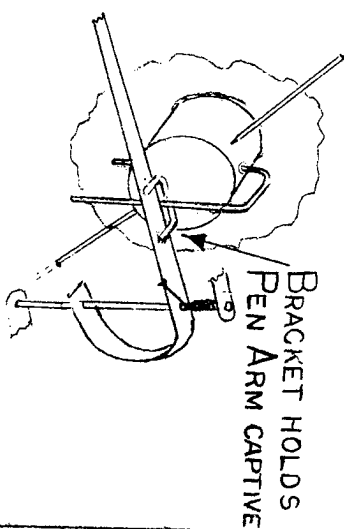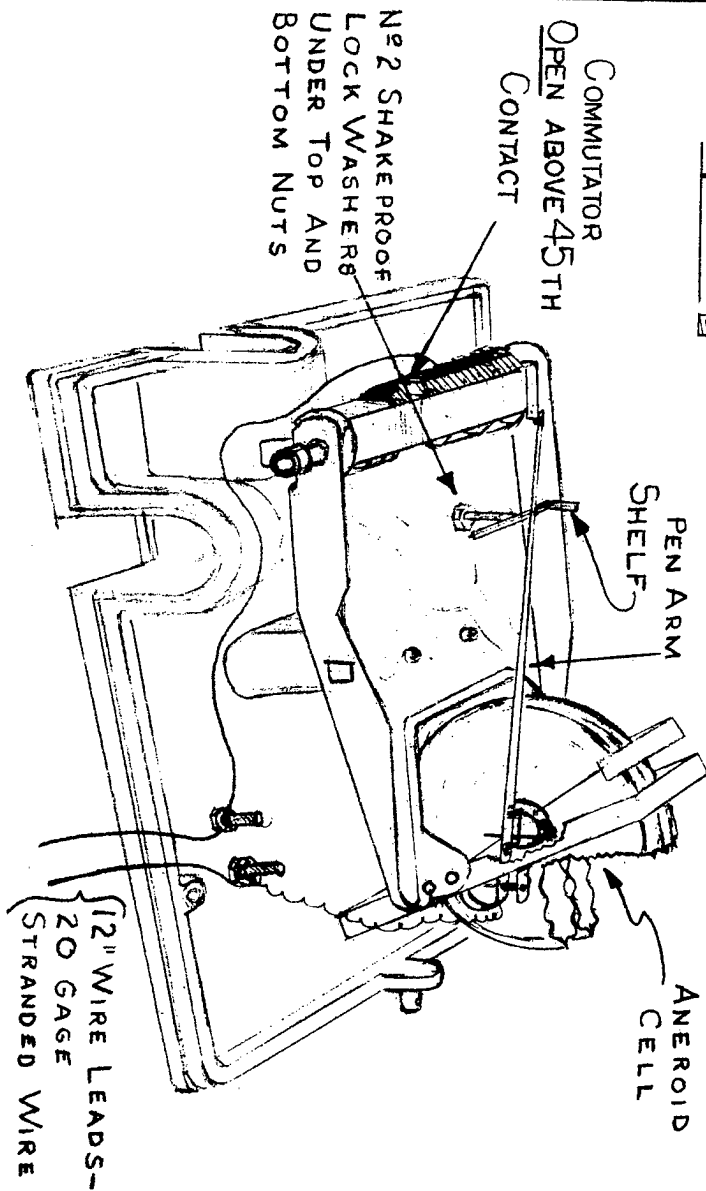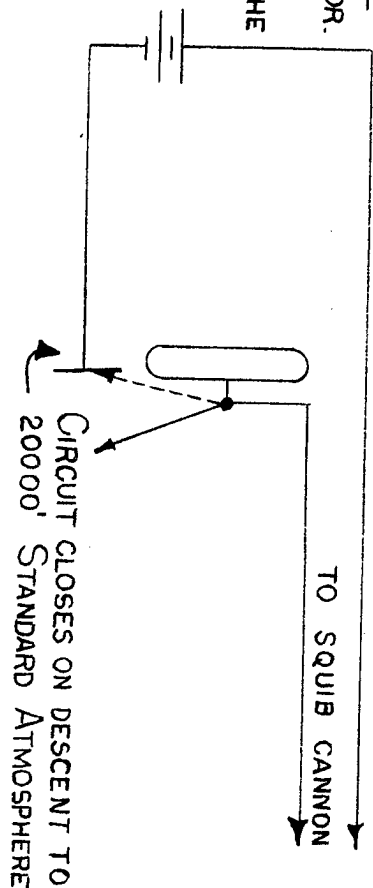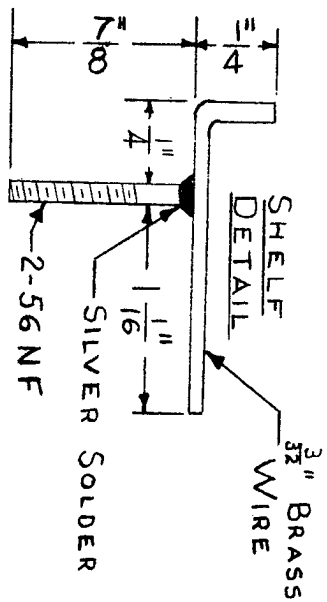
FIG. 12

NYU BALLOON PROJECT

FLIGHT TERMINATION SWITCH

DATE 7-27-48   ED48-70A

Drill $\frac{1}{4}$" – Ream .2815 $^{+.0005}_{-.0003}$

Thd $\frac{1}{2}$-20NF

$\frac{5}{32}$" Drill

$\frac{3}{16}$" Drill

$\frac{1}{4}$

$\frac{47}{64}$

$1\frac{5}{16}$

2

$\frac{7}{16}$

$\frac{11}{16}$

Tap $\frac{1}{2}$-20NF

$\frac{9}{16}$ $2\frac{13}{16}$

$\frac{3}{32}$ Drill Thru

Countersink Both Ends

$\frac{1}{32}$

$\frac{5}{16}$

.281 $^{+.0000}_{-.0005}$

A ——— A

Section A-A

B

Harden Drill Rod Bullet

Detail B

Finish Edge As Per Solid Line, Not As Broken Lines

Fig. 13

N.Y.U. Balloon Project

Line Cutter Cannon

LHM   11-15-48

ED48-117A
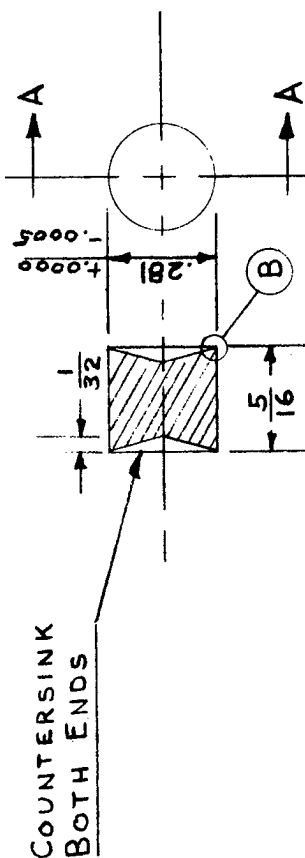
Notes:

For Use With:-
1. DuPont S-64 Squib (3' Wires)
2. 500# Test Parachute Shroud Line

Part	Material
Cannon	24 or 61ST Al
Cap	24 or 61ST Al
Bullet	Drill Rod Or Cast Lead

NYLON LINE

SQUIB

BULLET

TO BAROSWITCH CIRCUIT
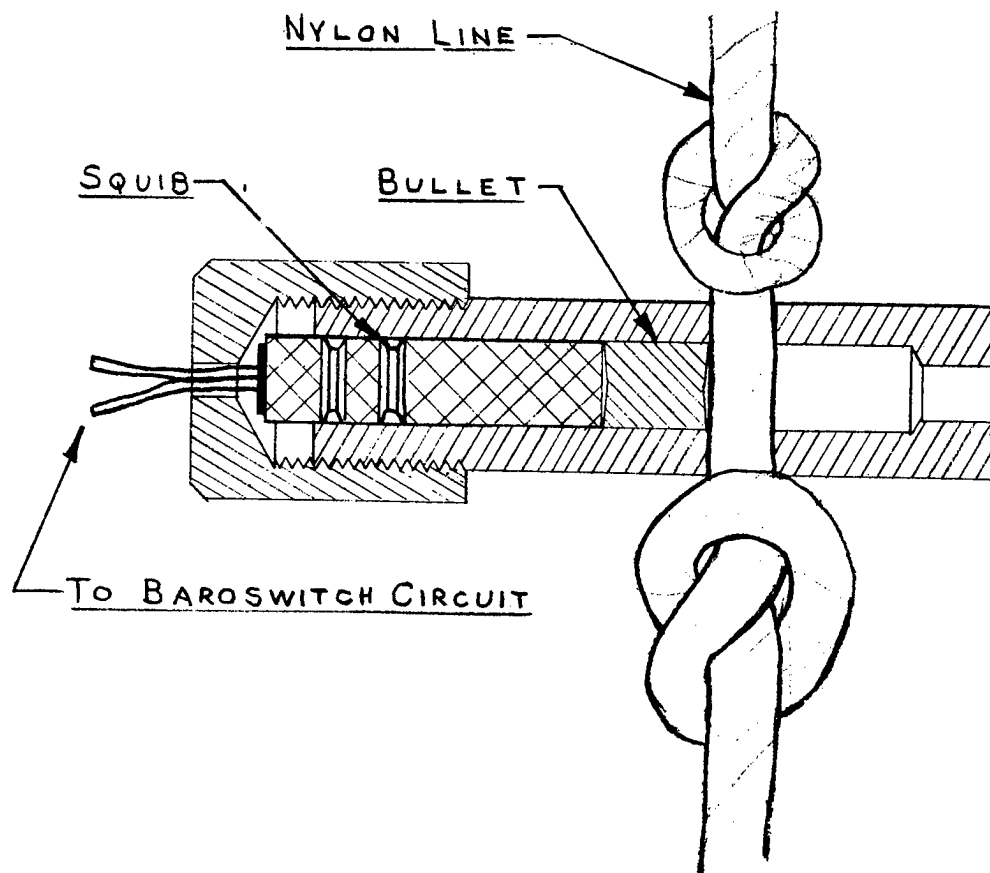
NOTES
    FOR CANNON DETAILS SEE ED 48-117A
    USE KNOTS ABOVE AND
        BELOW CANNON
    SQUIB- DUPONT S-64

FIG. 14

D. Accessory Flight Equipment

On most flights, three pieces of equipment are added
to the train for special purposes. These are: (1) a
banner, (2) a drag parachute, and (3) safety weights.

The banner is a red or yellow cheesecloth rectangle,
3 x 6 or 6 x 12 feet, with aluminum spreaders at top
and bottom. Shown in Figure 15, the banner is tied
taut to the load line, and serves to reduce sidewise
swaying as the balloon rises. Due to the bright color,
it is useful in locating the balloon after being grounded
and acts as a warning to air craft during descent and
ascent. If thdolite stadia determinations are being
made, the banner can be used as one of the check points
on the train.

The drag parachute is inserted into the train above the
banner in inverted position and serves to retard the
ascending balloon somewhat, thus reducing the probability
of bursting due to excessive rates of rise.

To correct a too slow rate of rise, (which may result
from under inflation due to gage errors, freezing of
valves, or excessive adiabatic cooling of the gas during
inflation) two small bags of sand or shot are added to
the bottom of the restraining line. If it appears that
the balloon is not rising with the desired velocity as
it picks up the equipment, one or both of these safety
weights are cut free. The weight of each bag is equal
to the desired free lift, so that if the computed free
lift is not available, this lift may be supplied. Prior
to the adoption of this practice, it was necessary to sacri-
fice equipment or the balloon in such cases.

E. Tracking and Recording Instruments

Depending upon the nature of the flight, the weather condi-
tions, and the equipment available, gear may be added to
the flight train to aid in horizontal position determination
and altitude measurement. The discussion of suitable
equipment for such work is given in Section VII. In general,
the equipment added may be either radio transmitters or
gear of other assorted types. Each unit is rigged sep-
arately, with hooks at each end of the line segment.
Prior to the inflation of the balloon a thorough check
of all such equipment, especially radio gear, is made.
It is necessary to have spare equipment tested, calibrated,
and assembled for last minute replacement if failure is
detected at this time.

LIGHTWEIGHT HOOK

RIGGING

45°

BANNER CLOTH

1" MINIMUM HEM
IN TOP & IN BOTTOM

24 S.T. .028"WALL
3/8" AL. TUBING
TAPED AT BOTH
ENDS

B
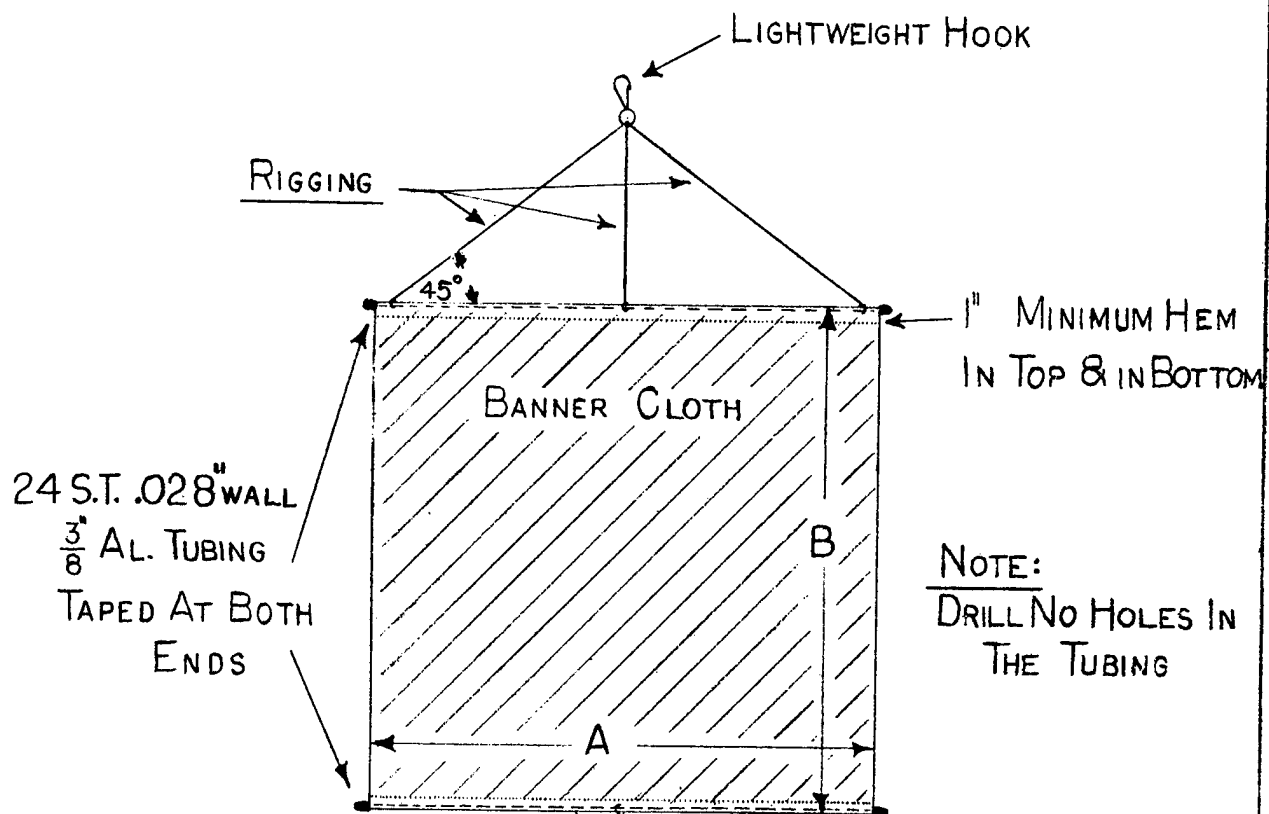
NOTE:
DRILL NO HOLES IN
THE TUBING

A

1'

CLOTH: CHEESECLOTH
20 THREADS × 20 THREADS PER INCH

SIZES:

A	B
3'	3'
6'	6'
6'	12'
3'	6'

COLOURS:
WHITE
YELLOW
RED

FIG. 15

NYU BALLOON PROJECT

BANNER

| Date: 5-19-48 | ED 48-56 |

Position of recording and radio instruments in the flight train is in some cases dictated by the size and shape of antennae or other special part. In general this type of gear is not placed below the altitude control equipment because of possible damage which might result from ballast being dropped upon them. Typical trains are shown in Figures 16, 17, and 18.

F. Flight Tools and Equipment

A list of tools and equipment and facilities which should be provided for any launching site is given in Appendix II.

IV. PRE-FLIGHT COMPUTATIONS

A. Lifting Gas and Rate of Rise

When the equipment for a flight is in readiness and the inflation procedure is to be begun, the total weight to be lifted must be determined. A weight sheet (shown in Appendix I) is filled in, with the final weight of each piece of gear with its rigging. In this work the weights of the equipment are measured in grams and kilograms for ease of computation. The gross load reported should be accurate to the nearest 200 grams. The amount of lifting gas to be used must be carefully figured to prevent incorrect inflation which might result either in the balloon failing to rise, or perhaps rising too fast and rupturing at its ceiling. After the total weight to be lifted is found, a percentage of this total is added to provide for lifting the load at some specified rate. With a given excess of buoyancy, a balloon will lift its load at an almost constant predictable speed. (The rate of rise will increase by about 25% at higher altitudes, due to the changes in balloon shape and decrease of air density.) Graph 1 of Appendix II shows the relationship between the free lift and the rate of rise, with free lift expressed as a percentage of the total or gross load (which includes the weight of the balloon itself). For example, if a gross load of 10.0 kilograms is to be lifted at a desired ascent rate of 600 feet per minute, 9.2% of the gross load should be added, giving a gross lift of 10.0 + .920 = 10.920 kilograms. (The rate of rise should not exceed 700 feet per minute if a standard appendix is used.)

It should be noted that this graph, derived from equations for spherical balloons, applies also to the tear-drop cells of General Mills, Inc., without regard for the balloon diamter.

G.M. 20 BALLOON
G.M. 202

APPENDIX

RIP RIGGING

FLIGHT TERMINATION
SWITCH

PAYLOAD

PARACHUTE
ML-132

BANNER - 3'×6'

ORIFICE BALLAST
ASSEMBLY

3'
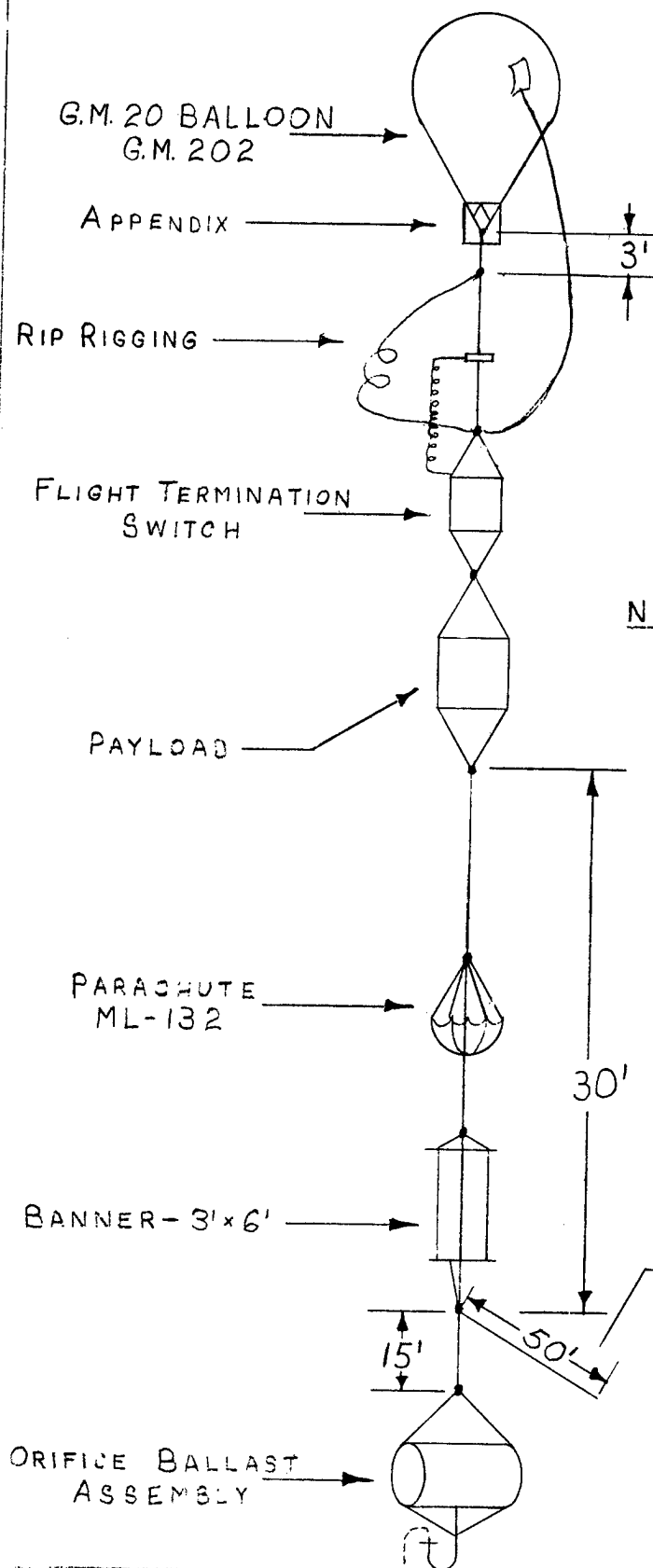
1500 gm FT. SWITCH
500 " RIGGING
2500 " PAYLOAD
500 " DRAG & BANNER
500 " RESERVOIR
1500 " BALLAST
7000 gm NET
4500 " BALLOON
11500 gm GROSS

NOTE:
CEILING - 59000 to 63000 ft.
All rigging 500 lb. test Nylon
2 Full Tanks Helium Req'd
Prob. Flight Dur. - 10 hrs.

30'

LAUNCHING
REMNANT

50'

15'

FIG. 16

NYU BALLOON PROJECT

PROPOSED FLIGHT TRAINS FOR
SERVICE FLIGHTS (COMPLETE)

DWN. BY: L, H M
DATE: 8-31-48

FT 48-X1

G.M. 20' BALLOON
G.M. 202 →

PARACHUTE
ML-132

BANNER - 3'×6' →

15'

50'

30'

LAUNCHING
REMNANT
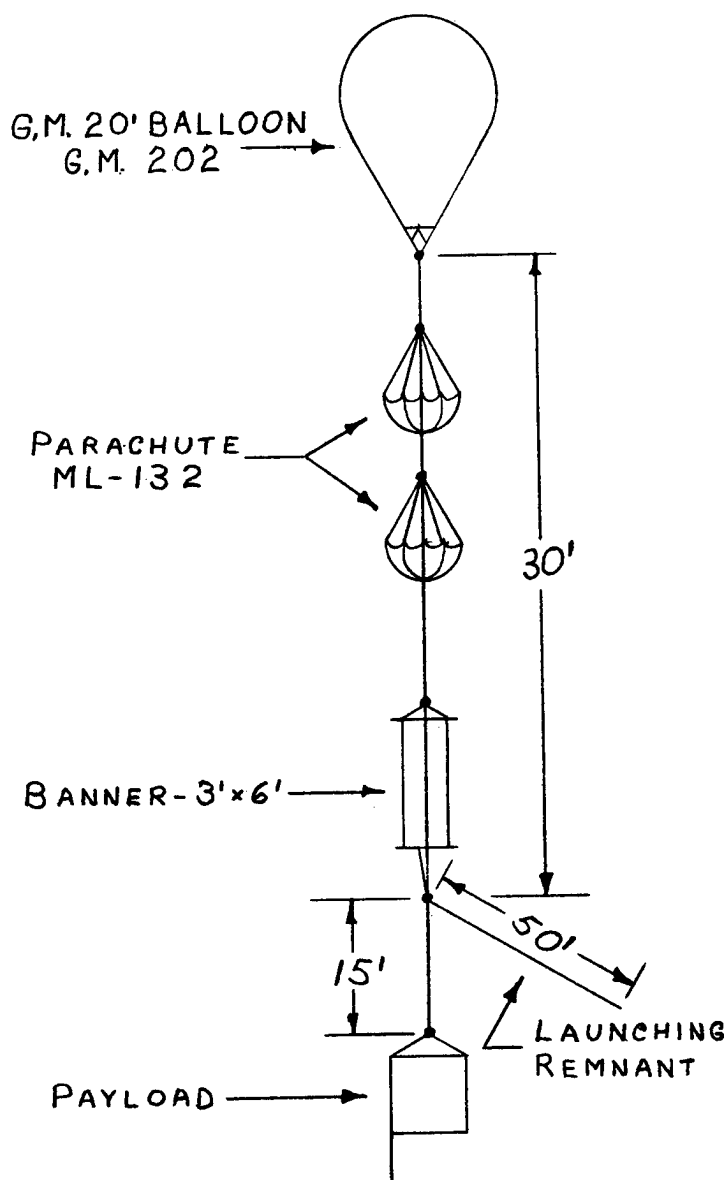
PAYLOAD →

```
 500 gm  DRAG CHUTES
 300  "  BANNER
2000  "  PAYLOAD
4500  "  BALLOON
─────────────────
7300  "  GROSS LOAD
```

NOTE:
   Use low rates of rise (500 ft
   per min) to prevent balloon
   failure during ascent.
   All rigging 500 lb. test Nylon.
   Max. Ceiling with this load:
      67000 to 70000 ft.
   Probable Ceiling: 45000 ft.
   since no appendix is used.
   Prob. Flight Duration - 3 hrs.
   1¼ Full Tanks Helium Req'd.

FIG. 17

NYU BALLOON PROJECT

PROPOSED FLIGHT TRAINS FOR
SERVICE FLIGHTS (SIMPLE GEAR)

| DWN. BY: L.H.M. | FT4B-X2 |
| DATE: 8-30-48 | |

WHITE THERMISTOR

20' BALLOON

APPENDIX

RIP RIGGING

BAROGRAPH & FLIGHT
TERMINATION SWITCH

DRAG CHUTE
ML-132

THERMISTER LINE

3'×6' BANNER

BALLAST
RESERVOIR

SOLENOID VALVE
& BALLAST METER

AM-1 TRANSMITTER
WITH PRESSURE
MODULATOR, TEMP. &
PROGRAM SWITCHES INSIDE

ANTENNA

3'

25'

170'

HOLD DOWN LINE
WITH LOOP

SAFETY WEIGHTS

SERVO CONTROLS

APPROX. WEIGHTS: (GMS)	
BALLOON	4200
BAROGRAPH	1500
FLIGHT. TERM. SW.	
WITH BATT.	1000
ALL LINE	400
ANTENNA	860
BALLAST ASSY.	
+ TRANSMITTER	17000
BALLAST	5000
BANNER AND	
DRAG CHUTE	450
TOTAL	30410
SAFETY WTS. - EQUAL TO	
FREE LIFT	

FIG. 18

N.Y.U. BALLOON PROJECT

PROPOSED FLIGHT TRAINS
FOR RESEARCH FLIGHTS
LHM
2-1-49   FT 49-1A

When the total quantity of gas needed has been computed, the lift requirement may be expressed in terms of the pressure of a number of cylinders of gas. It is not possible to assume that each tank of gas will give the same amount of lift, nor is it possible to use a gage which has not been experimentally calibrated to relate lift to pressure. For calibration of a gage it is sufficient to valve gas from an observed equilibrium temperature and pressure in a cylinder into a rubber balloon and then measure the total lifting capacity of the gas from the tank. Check points should be made with tanks under varying amounts of pressure. Figure 19 shows a sample gage calibration worked up for varying temperatures assuming the simple gas law

$$\text{Lift}_2 = \frac{P_2}{P_1} \times \frac{T_1}{T_2} \text{Lift}_1$$

This law applies to within ±1%. Note: Do not use Graph 6 without checking calibration of gage to be used. Ordinarily a whole number of full tanks of gas will not exactly supply the desired lift, which should be figured with not more than one-tenth full tank tolerance in excess (permit no under inflation). It is thus necessary to prepare partially full tanks and by combining full and partially full cylinders get the required total. It is necessary to allow the cylinders to attain equilibrium temperature after valving them before taking final pressure readings.

B. Length of Balloon Bubble

The volume of gas required for a given balloon may be expressed as the length of an uninflated bubble at the crown of the balloon. Graph 2 of Appendix II gives the relationship between bubble length and resultant inflated volume, using gross lift as an expression of volume. It will be noted that when the elevation of the launching site is markedly different from sea level, a shift in this curve is needed to accomodate varying densities of the atmosphere. The inflation of this bubble, which is pinched off by launching equipment or shot bags, will serve as a good check of the final amount of gas in the balloon, thus warning if the balloon is underinflated.

C. Expected Altitude

To predict the altitude to which a balloon will rise it is necessary to know the volume of the balloon, the total

SAMPLE
ONLY
REDRAW FOR EACH
GAGE AFTER CALIBRATION

110° 90° 70° 50° 30° F

Full Cylinder (6.81 kg)

3/4 Cylinder

1/2 Cylinder

Cylinder Pressure, psi (Gage)

Lift in Kg

NYU BALLOON PROJECT
Cylinder Pressure and
Temperature
Vs.
Lift
220 Ft³ Helium Cyl
June 30-1948
C48-21A
Note: Cylinder Volume = 1.45 Ft³
Gage Serial No. 683
Fig. 19
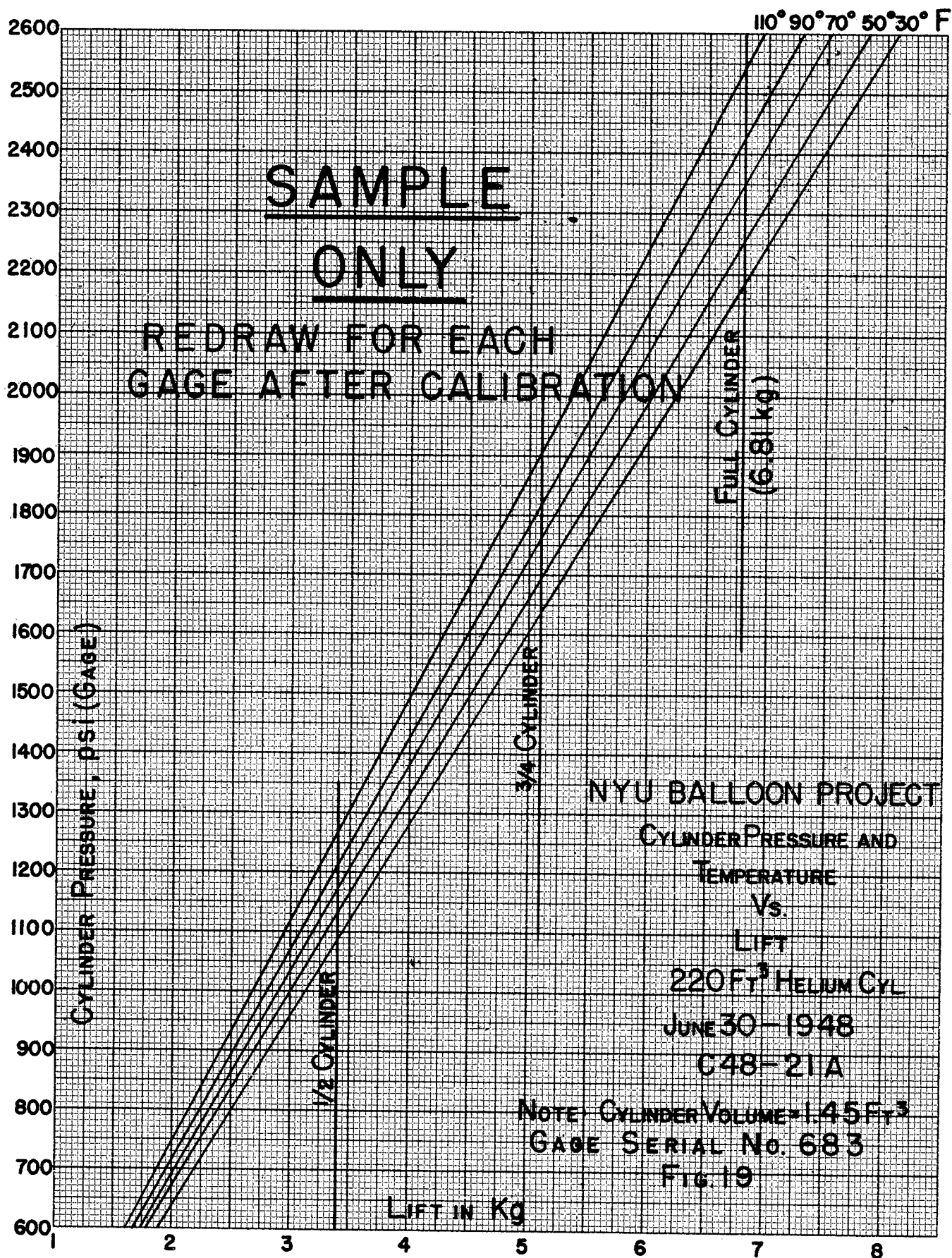
weight of equipment and balloon, the distribution of
density in the atmosphere and the buoyancy of the lifting
gas. Assuming that the lifting gas is helium, Graph 3
in Appendix II summarizes the relationship between gross
load and floating level for balloons of several diameters.
To use this graph to find the floating level of a balloon
of given size and load, enter with the required buoyancy
(equal to the gross load). Go vertically to the diagonal
line corresponding to the balloon size and then horizontally
to the extreme left-hand edge and read the altitude. The
volume of the balloon is related to density by the use
of the molar volume in this chart. Assuming observed
pressure and temperature distributions over selected
stations and the N. A. C. A. standard atmosphere, the
molar volume is given as well as the altitudes. Table 1
of Appendix II gives the N. A. C. A. Standard Atmosphere
relating pressure with altitude, and Table 2 gives the
variation of temperature with altitude. For local condi-
tions more exact measurements may be made using the
temperature and pressure distribution indicated by a
sounding rather than the standard. To do this, it is
necessary to compute the molar volume from this relationship

$$\text{molar volume}_z = 359 \text{ ft.}^3 \times \frac{T_z}{273^\circ C} \times \frac{1013.3 \text{ mb}}{P_z}$$

Example: Find the molar volume at 30,000 feet MSL where
the reported temperature is -30°C, and the reported
pressure is 300 mb.

$$\text{molar volume}_{30,000} = 359 \text{ ft.}^3 \times \frac{(273-30)^\circ C}{273^\circ C} \times \frac{1013 \text{ mb.}}{300 \text{ mb.}} = 1080 \text{ ft.}^3$$

This is the volume of a pound mol of any gas at those condi-
tions.

By plotting several points of this curve of molar volume
versus altitude, it is possible to locate very exactly the
altitude which corresponds to the molar volume to which
the balloon will go (found from Graph 3 or as follows).
This density or molar volume to which a balloon will rise
is given by the following formula:

$$\text{Molar volume} = \frac{\text{Balloon volume}}{\text{Gross load}} \quad \text{Gas Lift/mol}$$

Gas lift/mol = 11.1 kg/mol (using Helium)

D. Ballast Requirements

For a 20-foot General Mills balloon, a flow of ballast
of at least 200 grams per hour is needed to keep the bal-
loon aloft. Flow of the compass fluid used varies
(through a sharp-edged orifice) with the head, or vertical
distance between the free surface of the liquid and the
orifice. It is not affected by the temperature or pressure,
so long as the reservoir is properly vented.

Flow also varies with the size and shape of the orifice.
Using round spinnerette orifices, the flow of various heads
has been computed and is shown in Table 3, Appendix II.
From a knowledge of the minimum head to be expected (de-
pending on the construction of the ballast reservoir and
its connection to the orifice), the desired rate of flow
can be obtained by proper selection of orifice size. While
200 grams per hour has been used successfully for the
usual floating altitudes of the General Mills 20-foot cells,
this figure should be considered as an absolute minimum.
A short period check of the flow rate through each ballast
assembly prior to flight is recommended.

E. Altitude Sensitivity

The altitude gained by a balloon when its load is re-
duced by one kilogram is called its altitude sensitivity.
This amount is affected by the density of the atmosphere
at the floating level; for 20-foot balloons between
40,000 and 53,000 feet, it is roughly 1000 feet per kilo-
gram of weight lost. This weight is normally lost by
ballast dropping. The altitude sensitivity and the ballast
drop control the rate of rise of the ceiling. Graph 4,
Appendix II gives more exact values for this figure at
various altitudes.

F. Forms and Records

For the purpose of making standard pre-flight computations,
a series of computation sheets have been drawn up. These
are shown in Appendix I. Reward tags attached to components
of the flight train have encouraged the finders to protect
the equipment and report its location for recovery. The
tags, questionnaires, and the warning notices which are
used on appropriate gear where squibs or acid are used are
shown in Figures 20 and 21.

V. BALLOON INFLATION

A. Preparation of Balloon

From the moment the protective packing of the balloon is
removed, great care must be exercised to prevent tears

DANGER! ACID!

EMPTY THIS ON GROUND
BEFORE HANDLING

DANGER! FIRE!

CUT THESE WIRES
BEFORE HANDLING

REWARD NOTICE

This is special weather equipment sent aloft on research by New York University. It is important that the equipment be recovered. The finder is requested to protect the equipment from damage or theft, and to telegraph collect to: Mr. C. S. Schneider, New York University, 181st St. & University Heights, Box 12, New York City, U.S.A. Phone: LUdlow 3-6310. REFER TO FLIGHT #_____

A_____dollar ($) reward and reasonable reimbursement for recovery expenses will be paid if the above instructions are followed before September 1949.

KEEP AWAY FROM FIRE. THERE IS KEROSENE IN THE TANK.

Figure 20
Sample warning and reward tags

QUESTIONNAIRE

Please answer this and send to us so that we may pay you the reward.

1. On what date and at what hour was the balloon discovered?

2. Where was it discovered? (Approximate distance and direction from nearest town on map?)

3. Was it observed descending? If so, at what time?

4. Did it float down slowly or fall rapidly?

5. How much kerosene was there in the tank?

Remuneracion

La materia ha volado con este globo desde la Nueva York University para hacer investigaciones meteorologicas. Se desea que esta material se vuelva para estudiarle nuevament.

Con este motivo, se dara una remuneracion de _____ dolares norteamericanos y una suma proportional para devolver todos los apartos en buen estado. Para recibir instrucciones de embarque, comuniquense con la persona siguiente por telegrafo, gastos pagados por el recipiente, refirriendo al numero del globo _____.

CUIDADO!
PELIGRO DE FLAMA, HAY KEROSEN EN EL TANQUE.

C. S. Schneider
Research Division
New York University
University Heights
Bronx 53, New York

Figure 21
Sample Spanish reward notice and English questionnaire.

and pin holes from being made in the fabric. For example, the film is so easily injured that it is not safe to lay a folded-up balloon on a bare table-top or other hard surface on which sand or splinters might be found. For this reason a clean ground cloth of canvas should always be used for the lay-out of the balloon. Once the balloon has been laid out on the ground cloth, it is made ready for inflation and the rip line of the flight-termination gear is inserted into the cell (see Section III, C).

B. Use of Shot Bags and Releasing Device

While the balloon is being inflated it is necessary to hold it in position. Under conditions of calm wind, this may be accomplished by simple fastening heavy weights to the loading ring and allowing the entire balloon envelope to rise freely above its anchor.

Since only 10 to 20% of the balloon is full at the surface when the inflation is complete, it is possible to restrict the volume filled and so cut down the area exposed to the wind on days which are not calm. The volume required can be expressed as the length of the bubble collected at the head or top of the balloon. Having determined the desired length (see Section IV, B), the remainder of the balloon may be held down on the ground cloth by weighted bags wrapped in protective sheets of polyethylene (see Figures 22 and 23). Elliptical shot bags, weighing 100 pounds, are used to hold the base of the bubble to be inflated. Twenty-pound sand bags are used to keep the appendix closed to prevent filling of the balloon with air and to restrict the uninflated folds of the balloon. A more elaborate system of holding the gas in the upper section of the bubble makes use of the General Mills releasing device shown in Figures 24 and 25. Mounted on wheels, this mechanism is rolled into position with the head of the balloon lying across the platform. The protective roller arms lock into position holding the bubble until launching. This device is used with large loads when shot bags might roll or slide off the balloon. As the arms open outward as well as upward when the locking pins are removed, it is necessary to position the platform with the arms opening away from the bubble.

C. Inflation Techniques

When the balloon is manufactured, a polyethylene inflation tube about 4" in diameter is inserted. This tube extends from a few feet outside the appendix to near the top of

HEAVY DUTY PARTITION OR
TIES SPACED ALONG LENGTH
OF MINOR AXIS TO HOLD SHAPE

LIFTING HANDLES OF HEAVY
PARACHUTE WEBBING, STICHED ON
AS SHOWN

$15''^{+0.125}_{-0.00}$

$8''$

ALL SEAMS TRIPLE STITCHED

USE $\frac{1}{2}''$ ROD FOR INSERTED
BACKBONE

$22''^{+1.0}_{-1.0}$

WEBBING TIES

DRAW STRING

FIG. 22

NYU BALLOON PROJECT

ELLIPTICAL SHOT BAG	
Date 7-6-48	ED 48-62
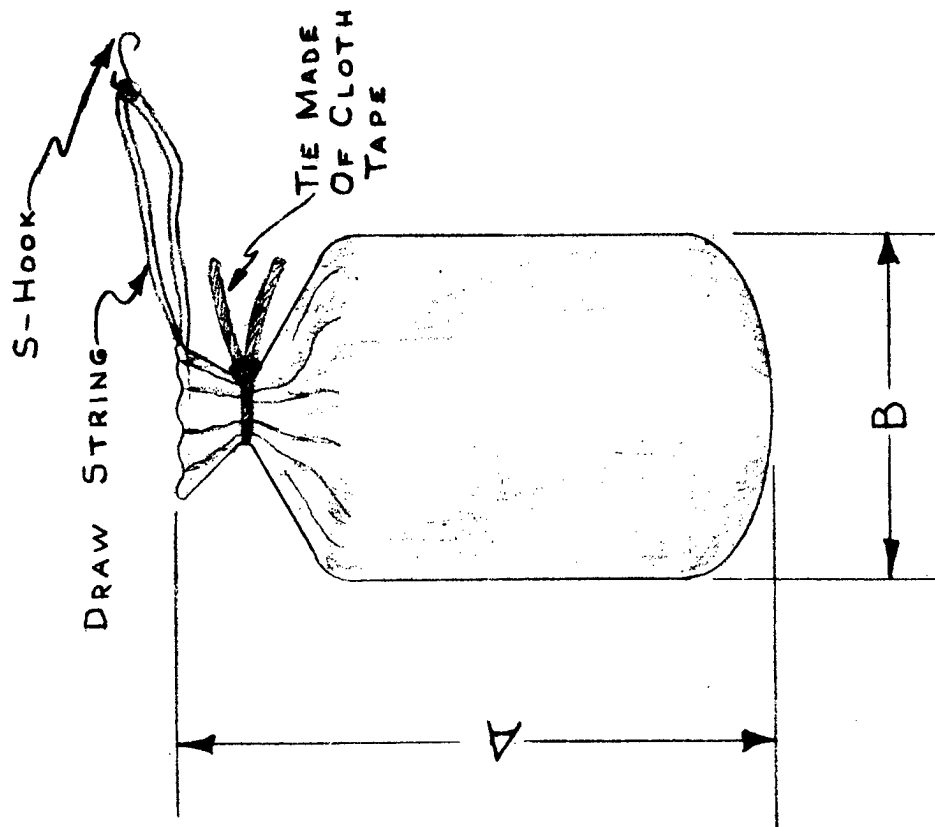
BAG SPECIFICATIONS

TYPE	A	B	BOTTOM
40# SAND	12"	10"	DOUBLE
40# SHOT	7"	6"	DOUBLE
SAFETY WT.	5"	3"	SINGLE

MATERIAL-HEAVY CANVAS DUCK

S-HOOK

TIE MADE OF CLOTH TAPE

DRAW STRING

A

B

FIG. 23

N.Y.U. BALLOON PROJECT

SAND AND SHOT BAG
SPECIFICATIONS

DRAWN BY LHM
DATE 11-23-48

ED48-122A
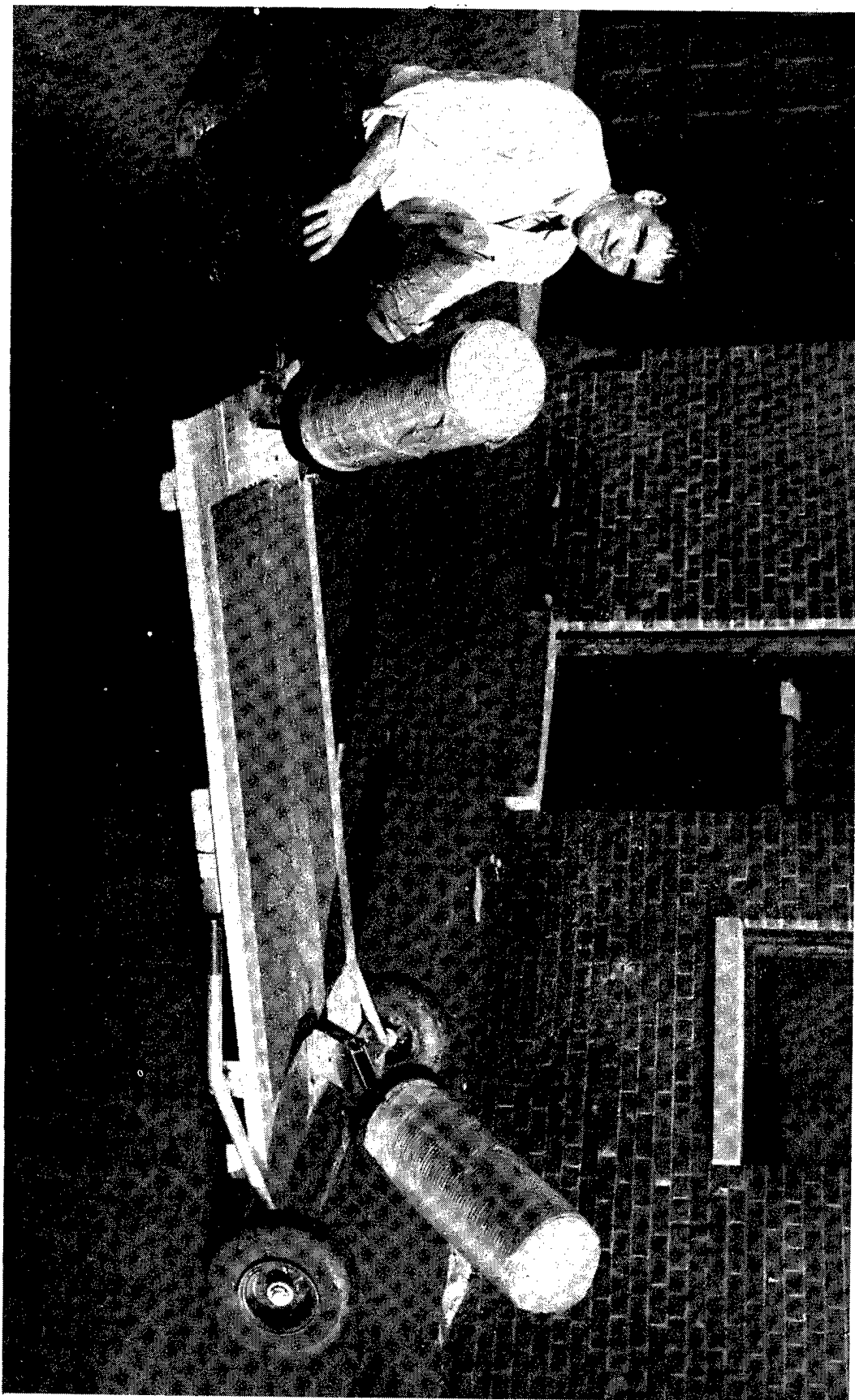
Figure 24
General Mills launching platform for large balloons.
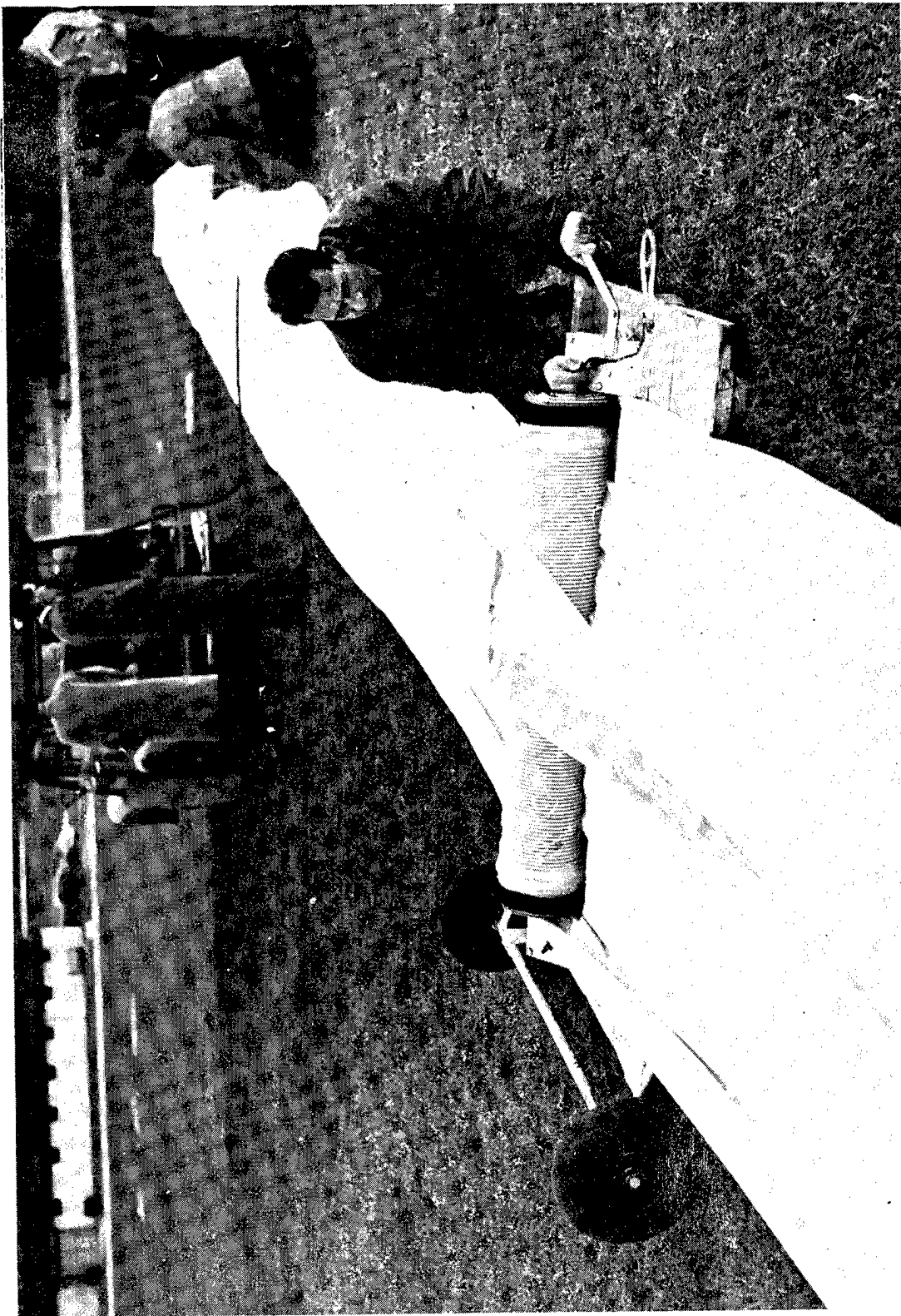
Figure 25

Launching platform with balloon fixed in place
for inflation.

the balloon and permits gas to be introduced into the
top of the cell first. As the balloon is laid out and
shotbags are positioned, this tube must be kept clear.
At the point where the bubble is pinched off the folds
of the balloon are carefully divided; the inflation tube
is made as free as possible with only one layer of poly-
ethylene above and one below it. The tube is then pulled
up above and between the arms of the releasing device or
the heavy shot bags, and the remainder of the fabric is
pinned down so that no shifting will permit premature re-
lease.

Depending upon the load to be lifted and the rate of rise
desired, a pre-computed amount of helium is fed into the
balloon (see Section IV, A). This amount is determined
by noting the equilibrium pressure and temperature of
the gas in each cylinder. A manifold is used to feed the
gas from the tanks to the inflation tube in the balloon.
Shown in Figures 26 and 27 this manifold system consists
of an adjustable number of flexible pigtails leading into
a main line of heavy copper tubing. This main line and
the fittings are capable of withstanding the full tank
pressure of about 2500 feet psi. Two pressure gages are
included in the main line and it is thus possible to make
last-minute checks of the amount of gas (pressure) in
each tank. (Due to variable gage-calibrations, it has
been found necessary to establish the lift-pressure ratio
of each gage before using it.) In the main line of the
manifold, two valves control the gas flow. The inflation
tube is often initially twisted when the balloon is first
laid out. A small amount of gas at very low pressure
should be valved into the tube to strengthen it. In addi-
tion to the fine valve control required for this pre-
liminary gas feed, it is also necessary for a manifold
valve to permit high gas flow from the tanks even when
the pressure is greatly reduced. For this, the coarse
globe valve is used.

Once the tube has been checked, inflation should proceed
as rapidly as possible. The balloon is outdoors and so
subject to buffeting by the wind. The limiting factor
of speed of inflation is the vibration of the fabric
near the open end of the inflation tube.

As a result of the extreme cooling of the rapidly expanding
gas, the manifold and the tank valve generally become
coated with frost. Too rapid cooling may actually cause
the valve to freeze shut.
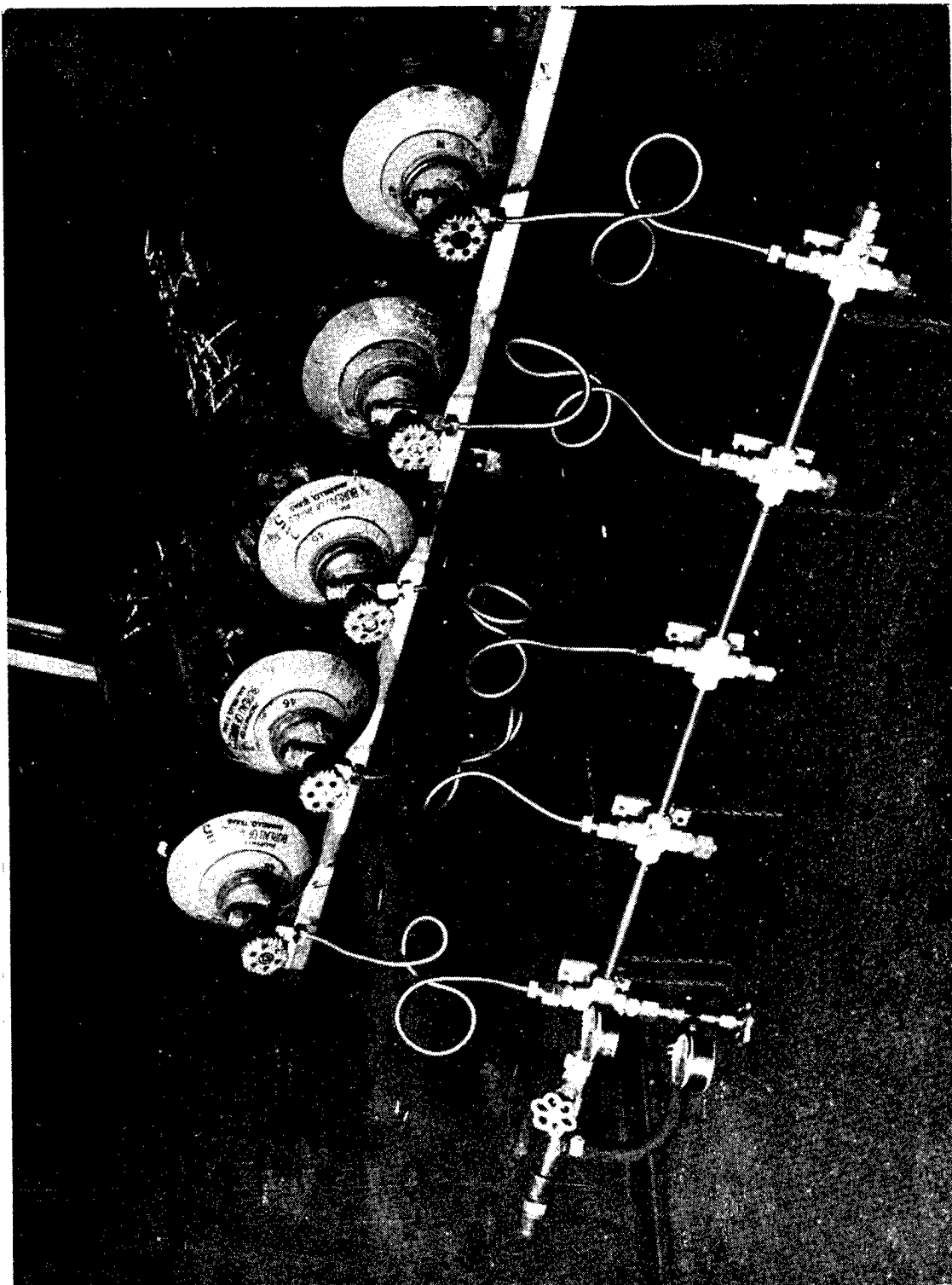
Figure 26
Five Tank Helium Manifold

SCALE 1:2

HOLES PUNCHED THROUGH BOTTOM OF
STANDARD TIN CAN (APPROX. $\frac{3}{32}$" DIA.)

$2\frac{5}{8}$"

BALLOON INFLATION TUBE
TAPED AROUND DIFFUSER

$4\frac{1}{2}$"

3"

SILVER SOLDERED

1"

1" I.D. RUBBER HOSE
FROM MANIFOLD
ATTACHED HERE

BRASS TUBE
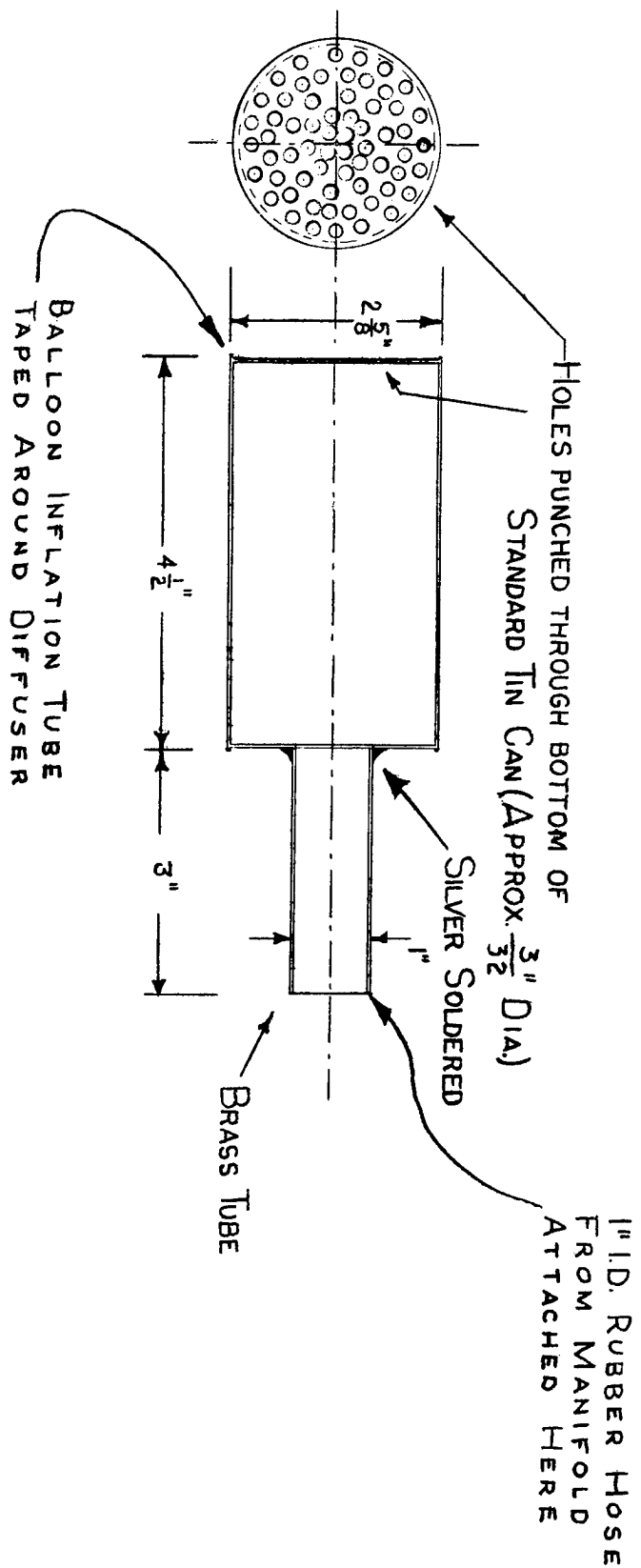
FIG. 27

NYU BALLOON PROJECT

TYPE 2 DIFFUSER

DATE 8-25-48 ED48-76A

-46-

The effect of this cooling is evidenced in the lifting power of the gas. When a rapidly filled balloon is launched immediately after inflation, it has less lift than desired and may even be "heavy" rather than buoyant. 20°C cooling will make balloon 1% heavier. This may be 25% of free lift. In the inflation of the 70-foot balloons where more gas is used, and the cooling effect is more often harmful, a heating unit is added to the inflation equipment. The gas passes from the manifold through a coil which is centrally warmed by a blow torch and on into the inflation tube. The gas should arrive in balloon no more than 20°C cooler than the air.

VI. BALLOON LAUNCHING

When the balloon inflation is complete, the inflation tube is removed from the balloon as gently as possible. There is apt to be constriction at the point where the bubble is formed by the launching arms or the shot bags. If the tube does stick at this point, great care must be given to freeing without ripping the balloon.

Should the balloon be torn in this or any other manner, it may be possible to patch the fabric and salvage the flight. The acetate-fiber scotch tape, used to attach the batten is used for patching. Transverse tapes are laid across the tear and the entire region is covered with a matting of tape.

When the inflation tube is freed and the restrained bubble is ready for launching, the lower portion of it is laid out down wind, as is all of the gear on the load line. The inflation is generally done in the lee of the hangar or "Y"-shaped wind screen (see Figures 28 and 29) with the bubble as close to the wall as possible. It is imperative that the wind direction be noted prior to launching and that the equipment be directly downwind from the head of the bubble. It is strongly recommended that a standard meteorological rubber balloon be inflated and tethered on a 150-foot line near the point of release to serve as a wind indicator. This balloon is much more effective than a standard wind vane.

All pieces of equipment and all on-lookers must be removed from the immediate vicinity to prevent accidental entanglement of the load line when the balloon begins to rise. Each piece of delicate gear to be carried aloft should be cradled by one man. As a signal given by the flight director (after checking to see everyone is ready and that the balloon will go in the desired direction), the bubble is released (see Figure 30). If "launching arms" are used, this is not

EYE BOLTS

120°
120°
120°
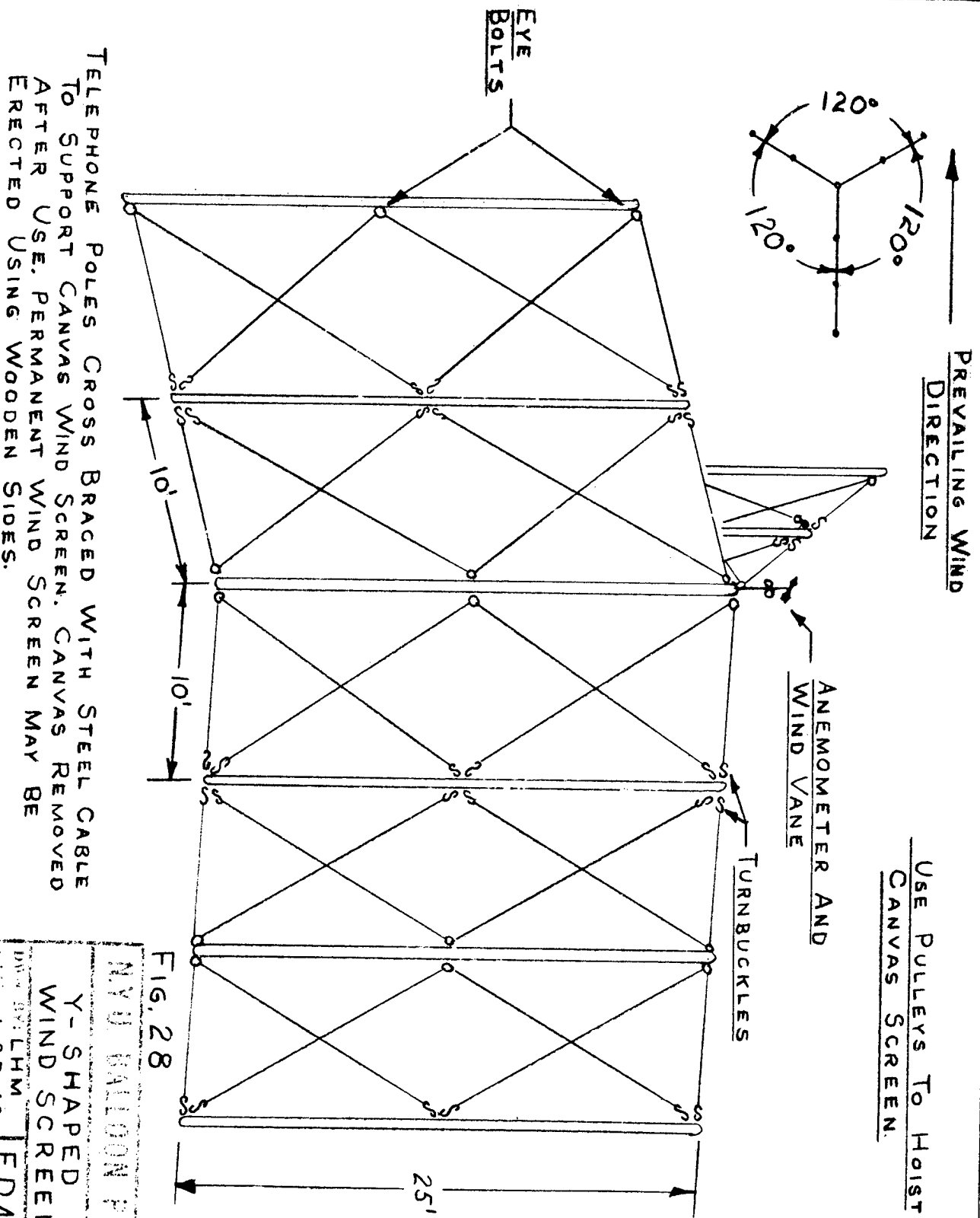
USE PULLEYS TO HOIST CANVAS SCREEN

ANEMOMETER AND WIND VANE

TURNBUCKLES

10'

10'

25'

TELEPHONE POLES CROSS BRACED WITH STEEL CABLE TO SUPPORT CANVAS WIND SCREEN. CANVAS REMOVED AFTER USE. PERMANENT WIND SCREEN MAY BE ERECTED USING WOODEN SIDES.

FIG. 28

NYU BALLOON PROJECT

Y-SHAPED WIND SCREEN

DRAWN BY: LHM
DATE 1-25-49

ED49-3A

Figure 29

WIND DIRECTION

1

SAND BAGS

SHOT BAGS

2

JUST AFTER REMOVAL OF SHOT
SAND BAGS

3

WIND CAUSES LOWER PORTION OF BALLOON
TO SPREAD OUT SAIL FASHION

4

BALLOON BEGINS
TO PICK UP LOAD

TO LOAD AND
HOLD-DOWN LINE

5
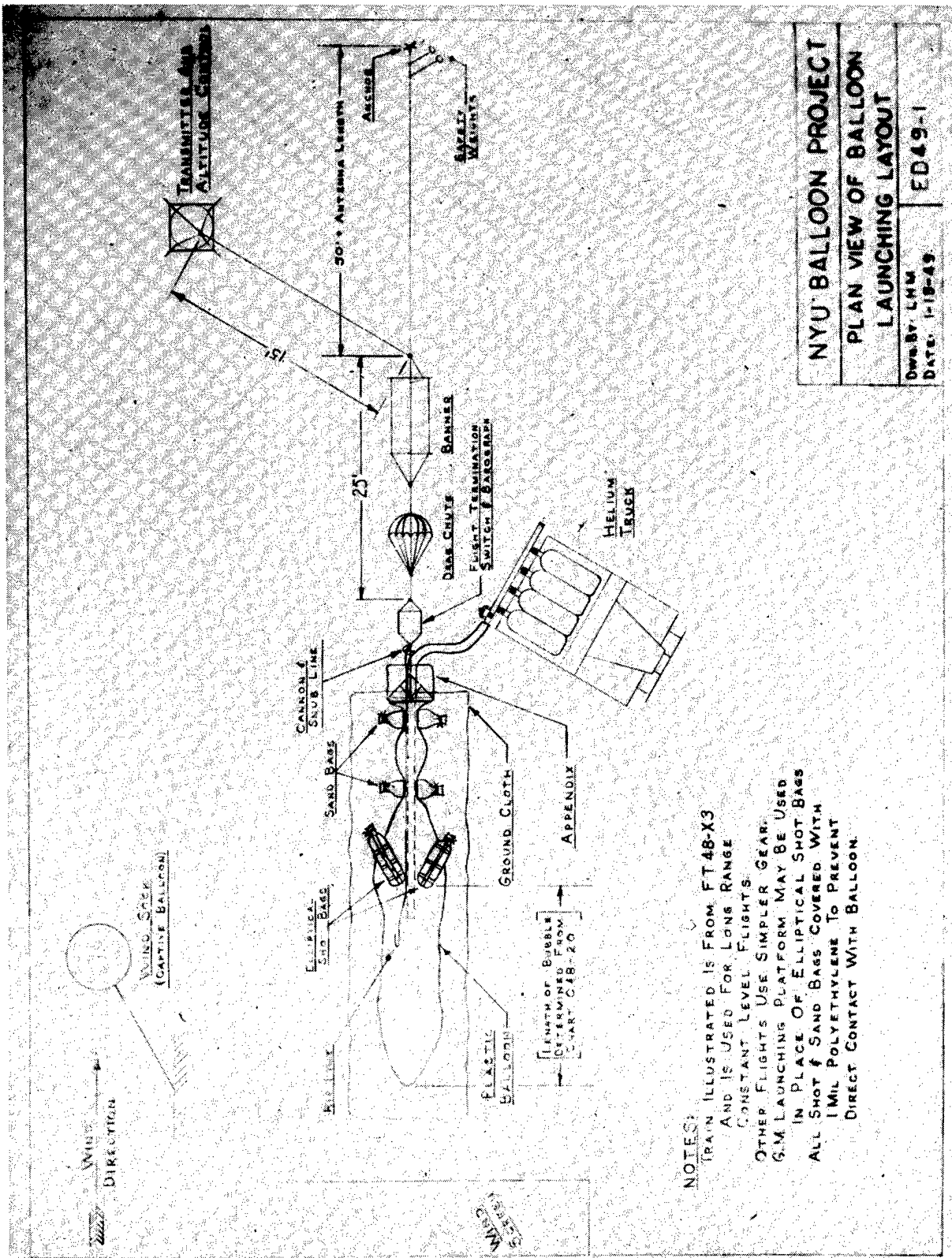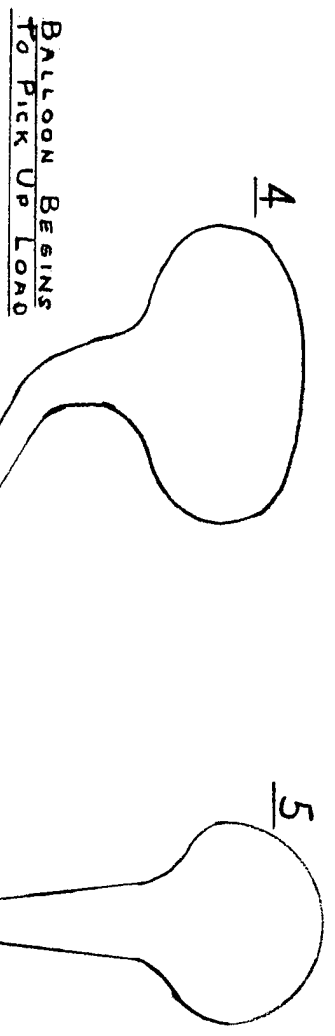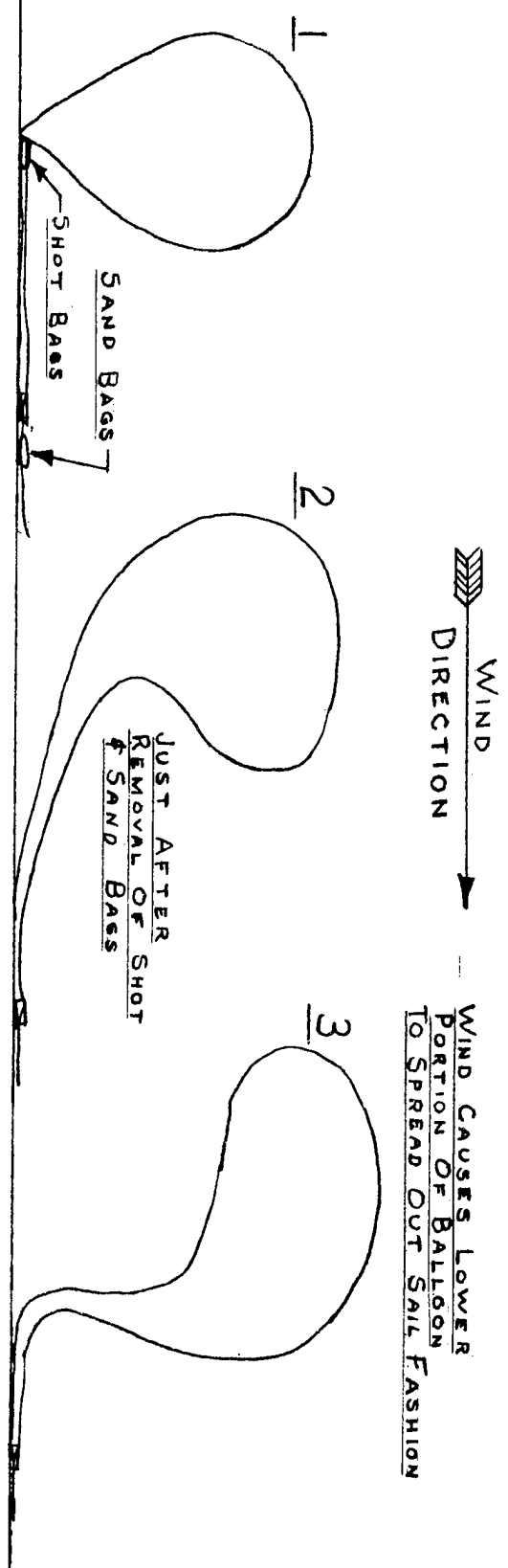
THE BALLOON TRAIN ASSUMES
A VERTICAL POSITION
WHEREUPON HOLD DOWN
LINE IS SEVERED

FIG. 30

BALLOON SHAPES DURING
LAUNCHING - REVISED
LHM
1-28-49
ED49-4

-50-

difficult, but if the two elliptical shot bags are employed, they must be lifted simultaneously upward and outward away from the balloon. As the cell rises, each piece of gear must be cradled by its bearer allowing it to be lifted vertically when the balloon passes overhead. In many instances where the wind direction is not constant at the surface or changes as the balloon goes upward, and exact downwind positioning of launching personnel will be difficult. It is often necessary for these men to run to one side or forward or backward to get directly beneath the balloon. In cases of extreme wind speed, it has been found necessary to load the lower pieces of equipment on to a truck bed before release of balloon and launch it by driving underneath the balloon.

It is possible to estimate the space required to launch a train of given length if the wind speed is known. By using the computed figure for rate of rise, the length of time required to lift the entire train is found. The distance the bubble will travel during this time is proportionate to the wind speed. For example, if a train 250 feet long is launched with the rate of rise at 500 feet per minute, a bubble will move downwind at 660 feet if the wind is 15 miles per hour (22 feet per second), and the man at the end of the equipment train must cover 410 feet in 30 seconds carrying the gear with him.

The use of a restraining line attached to the load line above any heavy gear or delicate gear is recommended. A loop in this restraining line is attached to a winch mounted on a track a few hundred feet downwind of the lowest piece of gear, or is held by a well-gloved man. The safety weights are attached near the end of this line. The balloon tends to pull the gear in beneath itself in calm or light winds, and may pull sidewise if the train alignment is not perfectly downwind; the restraining line withstands this pull. Thus tethered, the balloon is forced to come overhead of the equipment bearers, and they are able to launch with less difficulty and danger of equipment damage. If the apparent ascent rate is too slow, the restraining line is cut between the safety weights and the other pieces of equipment. If the rate of rise appears to be high enough, the restraining line is severed below the safety weights and they rise, completing the launching.

VII.   TRACKING AND ALTITUDE DETERMINATION

Following release, it is often necessary to know the position of the balloon and its height as long as possible. Several methods of position and height determination have been found useful. Advantages and limitations of each system are given.

A. Positioning Equipment

    (1) SCR-658

        The radio direction finding set SCR-658 has been found to be the most useful unit to track a balloon-borne transmitter, within its limited range. If the set is in good condition and the transmitter signal is good, it is possible to receive from a transmitter which is 150 miles away at an altitude of 50,000 feet. At this distance, the elevation angle is usually not high enough to be reliable, since below angles of $13°$, ground reflection of signals makes them nearly meaningless. The azimuth angle and the elevation angle, when above $15°$, are accurate to about $0.5°$. It is thus necessary to use two such sets on about a 100-mile base line to give a position fix. If the elevation of the balloon is determined independently, and the elevation angle is above $13°$, it is possible to locate the balloon-borne transmitter with one SCR-658.

        The installation and maintenance of SCR-658 requires the services of a specially trained man, while the operation procedure may be made by relatively unskilled personnel, with limited training. For details of the use of the SCR-658, see War Department publication TM11-1158A.

    (2) Theodolite

        The meteorological theodolite is useful on daytime flights when skies are clear for ranges up to 100 miles. If radio data are available to give height, the additional information obtained from this instrument--elevation and azimuth angle--will completely fix the balloon's position in three dimensions. When pressure data are known, two theodolites with a base line several miles in length will also uniquely locate the balloon. A third method, less accurate but still useful, is the method of stadia measurements. By carefully measuring, prior to release, the distance between two distinctive portions of the train and then noting the angular distance subtended during flight by these instruments, the altitude and hence all coordinates of the balloon may be determined.

        Regular and frequent checks must be made of the scale adjustments of the instruments and of the base plate

levels when the instrument is located out of doors.
For details of the use and care of theodolites,
see either the War Department publication TM-11-
423 or the U. S. Weather Bureau Circular "O".

(3) Aircraft Radio Compass

It has been found feasible to determine the posi-
tion of the balloon by following the signal from a
balloon-borne transmitter, using an aircraft radio
compass as receiving unit. In this way it is possible
to fly along a path toward the balloon, usually at
a much lower altitude, and, by noting the plane's
position where the compass reading is reversed, the
position of the transmitter is found. The main dis-
advantage of using this system is that aircraft is
needed, but there is no other method which will so
readily position the balloon over great distances
and periods of time. With this system, the limit
of transmission time is a function of the weight of
transmitter batteries which can be carried rather
than distance. It is possible to power a trans-
mitter to supply 2 watts, for about 15 hours, using
15 pounds (7 kilograms) of batteries. Longer periods
of transmission may be achieved by intermittent opera-
tion of the transmitters or use of heavier batteries.

(4) Radar

If ground radar is available, accurate positioning
over a limited range can be made. It is helpful
but not strictly required to add radar targets
(corner reflectors) to the flight train for such
tracking. Using radar, the elevation angle, azimuth
angle and slant distance out are obtained, giving
a complete fix on the balloon with one set. The
maximum distance to which appropriate sets can reach
is about 65 miles; such sets are the SCR-584, the
SPM-1 and the MPS-6. With good orientation and leveling
such sets have an accuracy of 1.0° and about 500 feet
of slant range. Because of the limited range, radar
sets are not generally useful. Attempts to use
radar mounted atop aircraft for aerial observation
have been abandoned in favor of the radio compass.

B. Altitude Determination

In early attempts to utilize standard radiosonde
pressure modulators they were found to be unsatisfactory.
The Diamond-Hinman system of counting signal changes

is not useful when the changes occur at a nearly constant altitude due to the width of the steps and the ambiguity of direction of vertical motion. Two pressure measuring systems have been found satisfactory for use in constant-level work and are discussed below. For a discussion of the radio transmitters which have been used (the standard T-69 and the NYU AM-1), see Technical Report No. 2, Balloon Project, New York University Research Division.

(1) Olland Cycle Pressure Measuring Instrument

This instrument, shown in Figure 31, is used in balloon flights as the primary pressure measuring unit, as it will continuously measure pressure without ambiguity. It modulates the transmitted radio signal at intervals whose timing is determined by the pressure of the air at the balloon's position.

As presently designed, the modulator contains a standard Signal Corps ML-310E radiosonde aneroid unit, a rotating cyclinder of insulating material with a metal helix wound around the cylinder, and a 6-volt electric motor which rotates the cylinder.

There are two contacting pens which ride on the cylinder and conduct electrical current when they touch the helix. One pen is fixed in position and makes a contact at the same time in each revolution of the helix. This contact is used as a reference point for measuring the speed of rotation of the cylinder. The time that the second one, which is linked directly to the aneroid cell, makes contact with the spiral, is dependent on the cylinder speeed and on the pen position which is determined by the pressure. By an evaluation chart, the atmospheric pressure can be determined as a function of the relative position of the pressure contact as compared to the reference thus eliminating all rotation effects but short term motor speed fluctuations.

Preparation of the modulator for flight consists of the following steps:

(a) Test the motor operation. When a 6-volt battery is inserted in the motor circuit with the proper polarity, the motor should run smoothly at one revolution per 60 to 80 seconds. Noisy operation is probably a sign of dirty or corroded
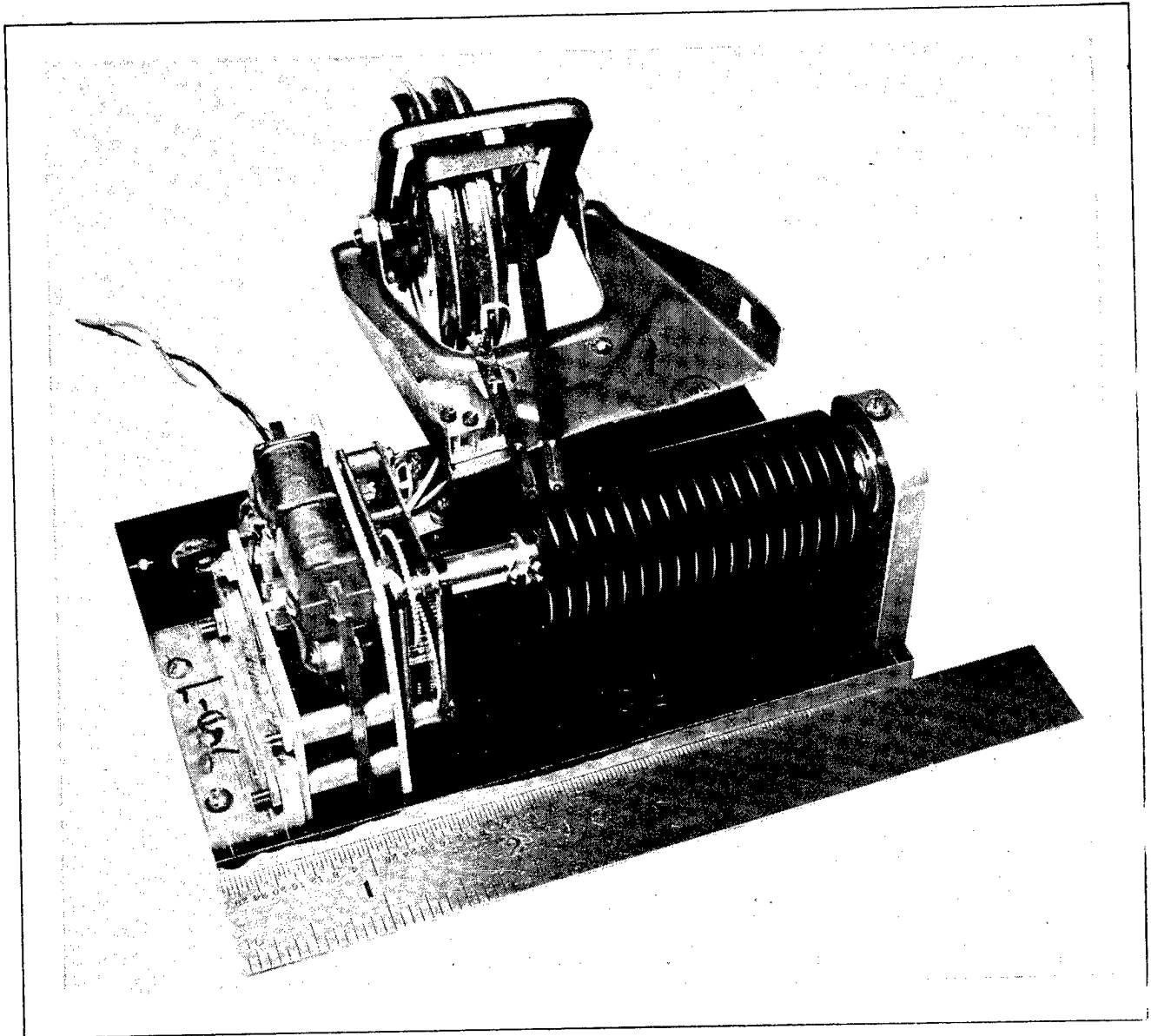
Figure 31
Olland Cycle Pressure Modulator

gears or poor alignment of the rotating cy-
linder. The motor gears may be cleaned with
carbon tetrachloride and a small clean brush.
If the trouble is due to misalignment, the in-
strument should not be used since this will
affect the rotation at a non-uniform rate and
thus destroy the entire accuracy of the record.

(b) Calibrate the instrument. The following equip-
ment is required for the calibration:

> Vacuum pump
> Bell jar
> Base plate with at lest 4 electrical leads
> Manometer
> Tape recorder

The vacuum pump should be capable of evacuating
the bell jar to a pressure lower than that to
be reached by the balloon in flight. A pressure
of ten millibars, corresponding to about
100,000 feet elevation is usually a good minimum.

Four wires are necessary to conduct the six
volts to the motor and to transmit the reference
and pressure signals. The wires must pass out
of the bell jar through an air-tight seal in
the base plate. The base plate also needs a
tube leading to the manometer and a tube to the
vacuum pump. It is advisable to use two sepa-
rate tubes rather than placing the manometer
lead in the same line as the pump lead in order
to obtain the pressure in the bell jar rather
than that in the pumping line.

In operation the negative line of the battery
leads is used as the ground connection of the
output signal.

A tape recorder such as the Brush Development
Co. model BL-902 oscillograph and amplifier
BL-905, is needed to record the signal both
during calibration and during the balloon flight.
The Brush recorder is used at present and the
discussion of the operation will be made in terms
of the characteristics of this instrument. When
using the slow speed of the recorder, which
feeds the paper at the rate of 30 centimeters
per minute, the distance between successive re-
ference marks will be 30 to 40 centimeters de-

pending upon the speed of rotation of the modulator motor. The pressure signal appears at any point along the record between or overlapping the references depending upon the pressure. A sample record of this sort is shown in Figure 32.

The Olland cycle acts as a switching unit for the test oscillator (see Figure 33) whose signal is fed into the Brush amplifier and finally to the recorder. By adjusting the resistors in the test circuit, the frequency of oscillation may be adjusted. Since within the usual range, the frequency of oscillation is approximately additive when the two signals overlap, the suggested frequencies are about 4 cycles per second for pressure and 8 cycles per second for reference. When overlapping signals are being recorded the frequency will be about 12 cycles per second which is easily recognizable on the record.

The calibration of the modulator unit should be in steps of 25 to 30 millibars in order to have at least three points within each turn of the helix.

Evaluation of the record is accomplished with the aid of a nomogram divided into 100 equal parts. The record is laid on the nomogram with the leading edge of the first reference on the zero line and the leading edge of the second reference on the 100th line. The position of the leading edge of the pressure signal is then read to the nearest third of a division on the nomogram. If one complete turn of the spiral represents 75 millibars, it is thus possible to read the pressure to an accuracy of one-three-hundreth of 75 or about one-quarter millibar.

In evaluating the record the tape should be kept parallel to the horizontal lines on the nomogram or perpendicular to the zero line in order to avoid errors in interpretation.

The total motion of the pen arm of the modulator is normally 12 to 14 turns of the spiral. Therefore, there will be the same number of points at which the pressure and reference signals overlap. The calibration curve (Figure 34) is drawn to show pressure from zero to surface pressure (about
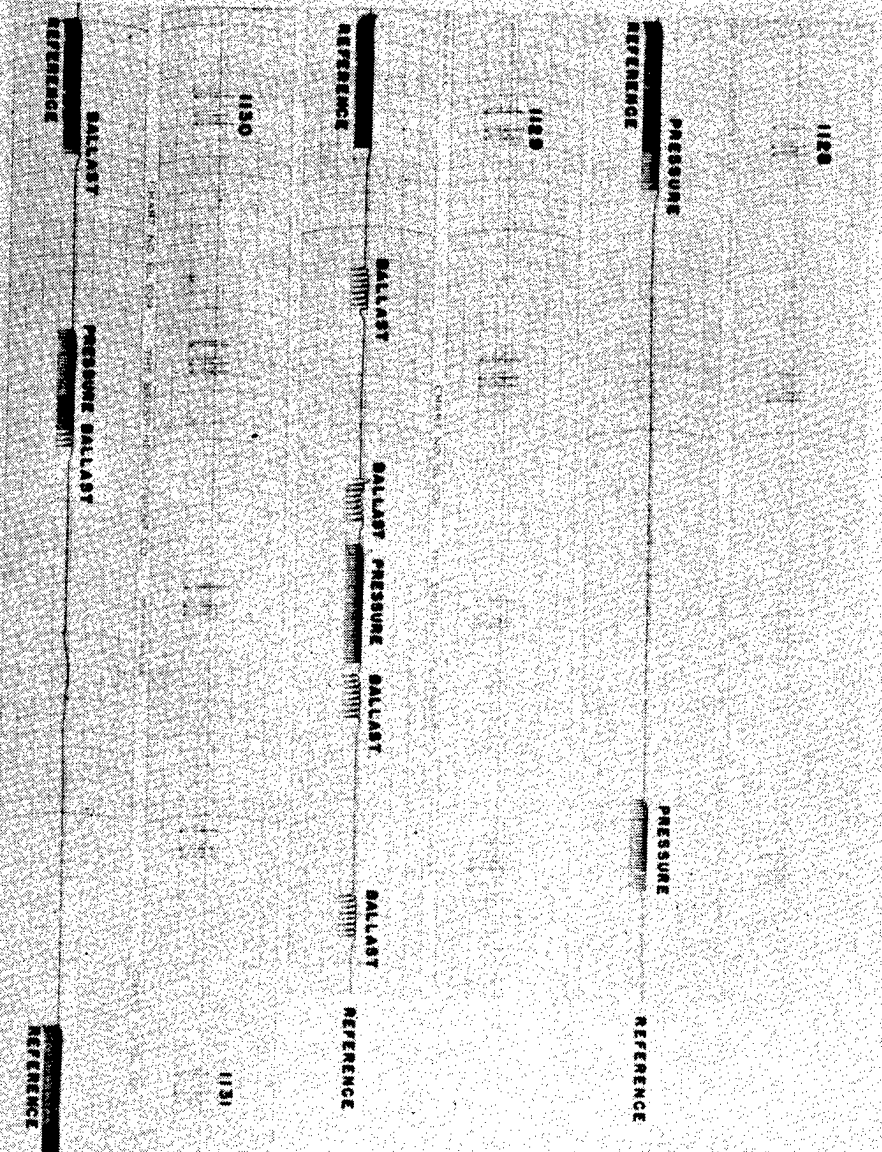
Sample Record Of Oiland Cycle Pressure Modulator
Signal As Recorded On Brush Oscillograph

C 49-6
Feb. 25, 1949-LHM

Reference— 9 cps
Pressure— 5 cps
Ballast— 2.5 cps

Time Signal Every 15
Seconds On Channel 2.

Figure 32

-58-

Olland Cycle
Test Oscillator

Fig. 33

ED48-125

LHM
11/30/48

-59-

PER CENT PRESSURE × 100

PRESSURE IN MILLIBARS

NYU BALLOON PROJECT
CALIBRATION CURVE
FOR OLLAND PRESSURE MODULATOR
Nº L-404
C49-5
FEB. 24, 1949   LHM

FIG. 34
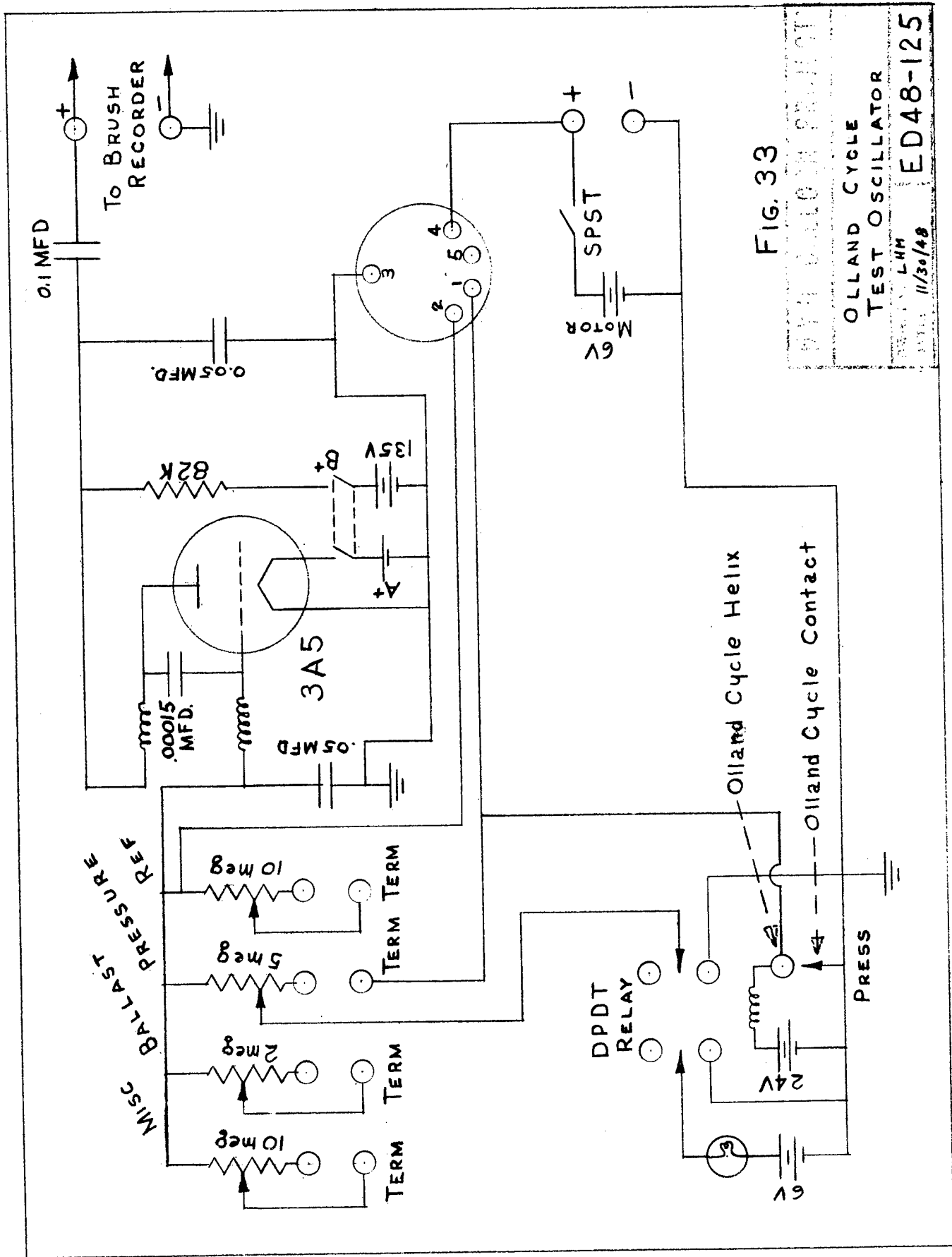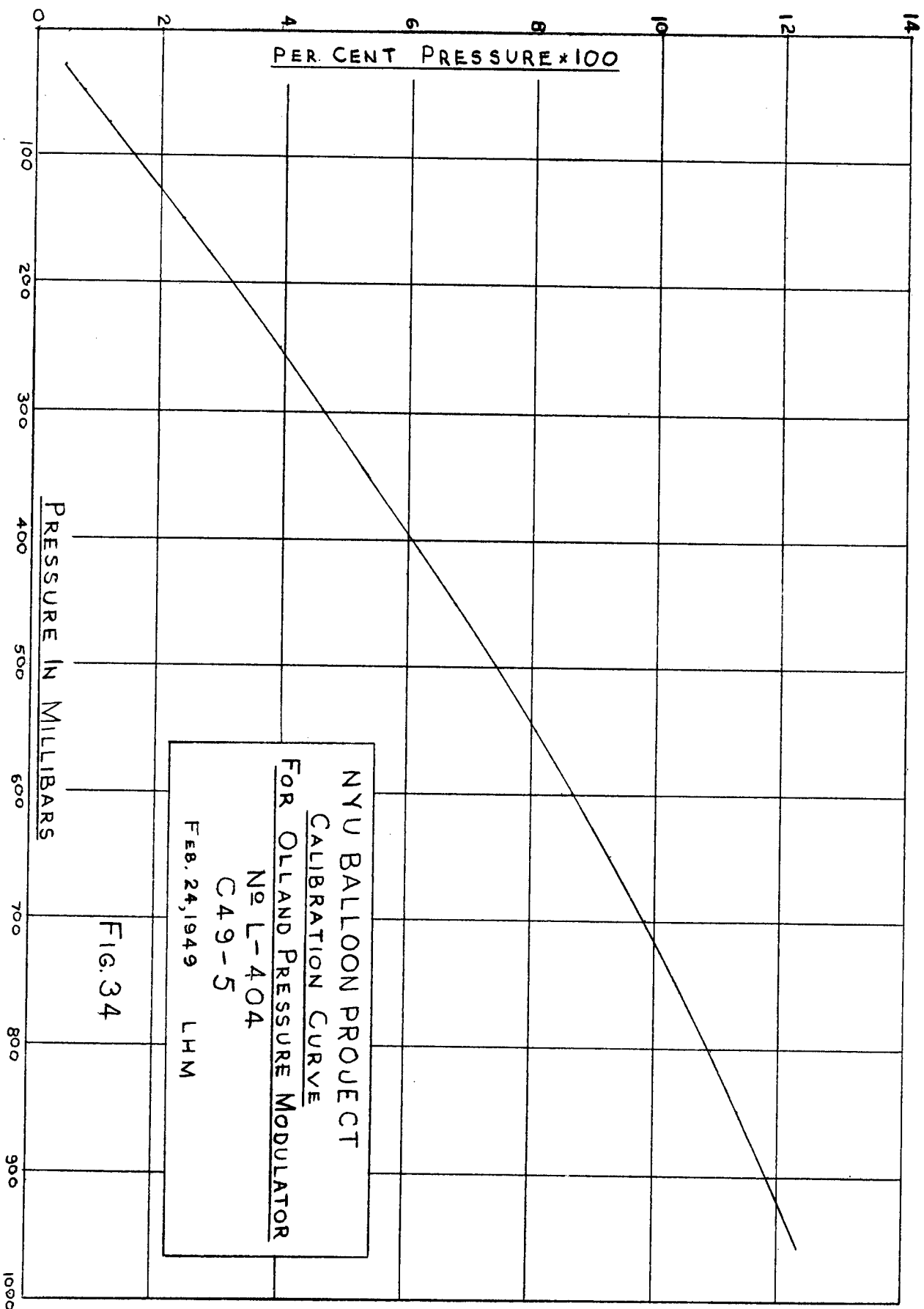
1020 millibars) against percentage of the turns
as read on the nomogram. The lowest pressure
reading is numbered as read and succeeding
pressures are plotted in a continuous ascending
series. When the pressure reading reached the
first overlap on the reference, it is called
100 percent; the second overlap is 200 percent
and so on until the last overlap which may be
1200 or 1300 percent.

(c) Pack the modulator and insert it inside the
transmitter box. The modulator should be pro-
tected from extreme cold since the motor opera-
tion becomes erratic when the temperature reached
30° to 40°C below zero. A box or paper cover
over the modulator will keep particles of in-
sulation and dirt from the moving parts.

(d) When the entire assembly has been made and in-
flation of the balloon is about to begin, the
transmitter and motor should be turned on and
reception of the signal tested. If any serious
trouble appears, the modulator should be re-
placed by another calibrated modulator since
any work on the instrument will probably change
the calibration.

During the flight, radio static and noise will
appear on the Brush record as pips which may re-
semble the transmitted signals and with increasing
distance or weakening transmitter the noise will
finally completely obscure the pressure record.
Careful tuning of the receiver will prolong
the record as long as possible. When tuning
the receiver, the sensitivity control of the
Brush amplifier should be turned to the least sen-
sitive position since any sudden change in the
tuning may throw the pen off its supports and
damage its glass tip.

When the flight reception is completed the re-
cord is evaluated exactly as in the evaluation
of the calibration record--using the same nomo-
gram. However, since the instrument is subjected
to different atmospheric conditions, the motor
speed may vary suddenly, giving false values for
the pressure. These values may be detected by
carefully observing the rate of rotation of the
motor, which is measurable by the distance be-
tween the reference marks. If there is a sudden

change in motor speed of five percent or more
from the preceding rotation, the pressure value
should be rejected. A slow, continuous change
in speed from minute to minute may be neglected
since it is probably a uniform change through-
out the rotation period. The motor speed will
decrease during the flight, as a result of the
low temperatures and the drop in battery voltage.
This of itself does not decrease the value of
the record, as long as the speed does not change
suddenly.

(e) Olland-Cycle Pressure Element Specifications

   (1) Pressure range: 1050 to 5 mb.

   (2) Desired accuracy: Surface to 300 mb $\pm$5 mb.
       300 mb to 50 mb $\pm$2 mb.
       50 mb to 5 mb less than $\pm$2 mb, $\pm$1 mb if
         possible.

       Highest accuracy and readability desired
       on low pressure end. Temperature compensa-
       tion, as required to meet pressure accuracy
       requirements for temperature, range +30°
       to -70°C or equivalent for medium and high
       altitude flights. Mean operating tempera-
       ture required more than 0°C.

   (3) Helix:

       Cylinder--made of insulating material with
       low temperature coefficient.
       Diameter 3/4 inch to 1 inch, length $2\frac{1}{4}$
       inch.

       Spiral--made of nickel or other metal which
       does not corrode in the atmosphere, .010
       inch or less in diameter.
       Eight turns per inch on cylinder.

       Check-points--Six points located between
       turns of spiral, starting with 9th turn,
       60 degrees apart.
       Made of the same material as the spiral.
       In the electrical circuit of the pressure
       signal.
       Suggested shape 1/16 inch diameter, round
       pin, flush with surface of helix.

General--Helix mounted in a rigid frame to prevent lengthwise movement or springing out through bending of a frame.
Joined to motor drive by a pin through both drive shaft and helix shaft.
When rotating at about 1 rpm duration of signals not over 3 to 4 seconds.
Surface of helix to be polished with rouge or crocus cloth.
Loading edge of the metal spiral will be true and smooth to within .0005 inch.

(4) Motor:

6 to 7.5 volts
1 rpm gear train
20 to 40 milliamperes drain
Constant speed--change of speed during any single revolution not more than 0.3%
Speed change at low temperature not more than ±20%

(5) Mounting of Unit:

Mounting in such manner that temperature changes and stresses will not change the relative positions of the aneroid and the helix. This may be done by mounting all elements on a $\frac{1}{4}$" metal plate or by mounting all parts in a frame supported on a single pedestal.

Mount unit in an easily opened, stiff single thickness cardboard or plastic box to protect it from other units in flight trains.

External terminal strip with four terminals connected to ground, motor, reference, and pressure.

Total weight not over 500 grams.

Overall dimension not over 5 x 5 x 4 inches.

To be mounted in transmitter, where insulation will prevent cooling below 0°C within 6 hours at air temperature of -40° to -50°C.

(2) Codesonde

The modified radiosonde built by Brailsford and Co., Rye, New York, called the codesonde, has been found valuable when knowledge of small variations in the height of the balloon is not required. Using this system, a radio transmitter is modulated by a Morse code signal which is a function of pressure (and temperature if desired). This system is useful for tracking a balloon with aircraft since no recording equipment is necessary for data interperlation.

Each combination of dots or dashes may be identified by ear, and with a calibration chart, the pressure which corresponds to the balloon's height may be thus determined by anyone who can read Morse code with a suitable radio receiver. The advantages of using this system for a balloon which is to be followed by aircraft include the fact that it is necessary to receive only one complete code group to completely identify the pressure level of the balloon. It is thus possible to interrupt the period of reception without permanently losing the altitude record. It is expected that a balloon transmitter which can be followed with an aircraft radio compass will be used in conjunction with this pressure modulator, giving three-dimensional position data.

(3) Barograph

Many balloon flights pass out of the range of even a network of receiving stations. When it is not possible, because of weather or other considerations, to follow the balloon with aircraft, a clock-driven meteorograph may be added to the flight train to record data, such as pressure and temperature. It is necessary to recover the balloon equipment to evaluate this sort of record. With inland release points, it has been possible to recover about 75% of all flights.

The model U-48 Lange barograph, shown in Figure 35, is designed to give a record of atmospheric pressure and the temperature of the barograph case. In order to obtain a maximum spread of the pressure record in the range at which the data is most useful, the linkages are arranged so that recording begins at about 500 millibars or around 19,000 feet, and may be continued as high as the balloon rises. The
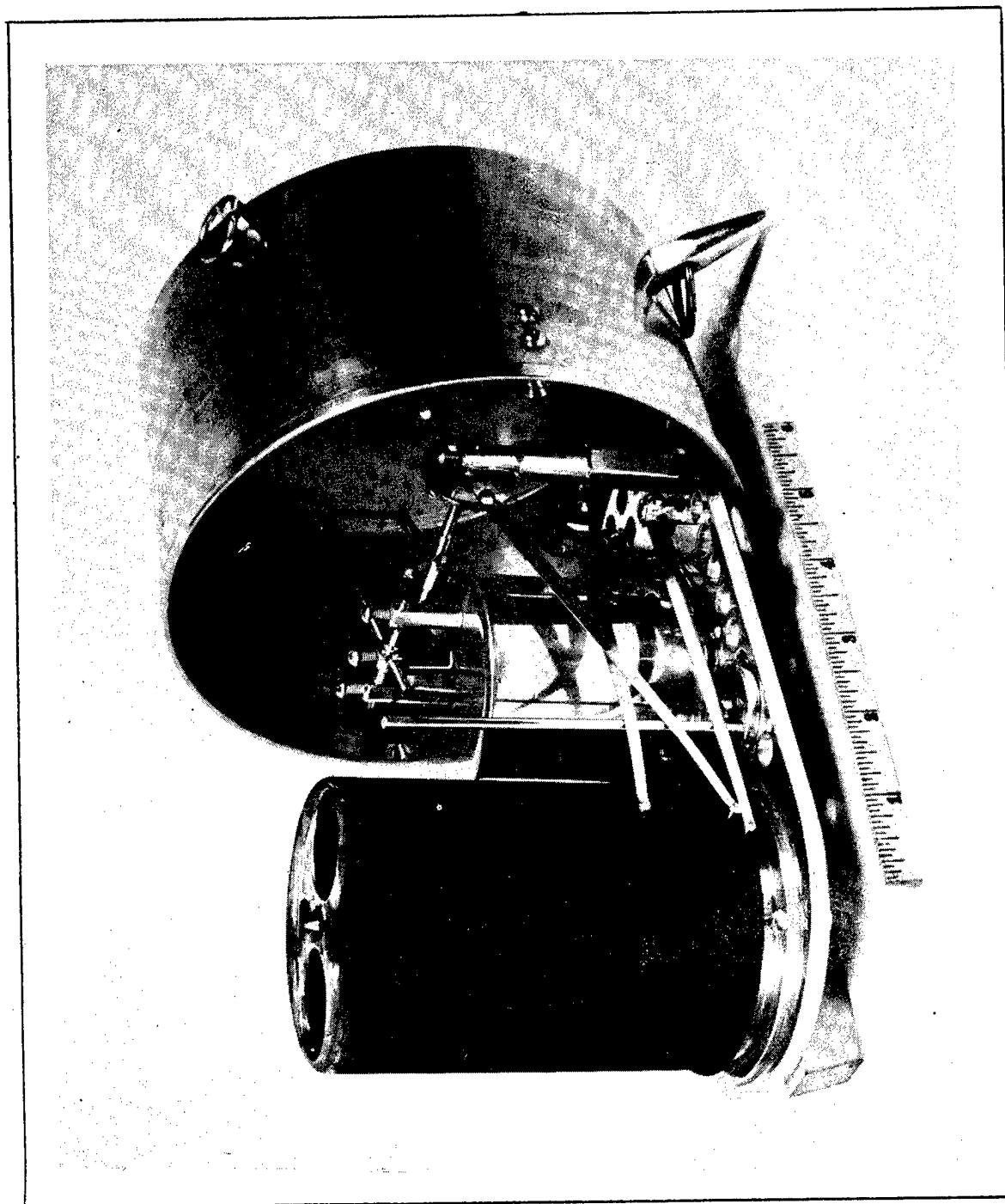
Figure 35
Lange Barograph Thermograph With
Smoke Unit on Recording Drum

temperature recording is confined to the lower
2 inches of the drum so as to interfere as little as
possible with the pressure record when the balloon
floats above 30,000 feet.

Recording is accomplished by three pens which scratch
carbon from a smoked aluminum foil. This method
eliminates the need for liquid ink and applies a
minimum of pressure to the recording drum.

The recording drum rotates once in twelve hours.
Therefore, if a flight lasts over twelve hours, the
trace will overlap. Such a record is shown in
Figure 36. The clock runs for 36 to 40 hours on
one winding.

Preparation of the barograph for use on a balloon
ascension requires the following:

(a) Place an aluminum foil about 10 inches long by
    3 3/4", .002" thick on the drum. Care should
    be taken to have the overlapping edge of the
    foil face in the direction of rotation of the
    drum so that the stylus slides off the edge in-
    stead of catching and tearing the foil. A few
    drops of rubber cement along each edge of the
    foil are sufficient to fasten the foil to the drum
    and will not interfere with removal of the foil
    after recovery of the barograph.

(b) Wind the clock. The clock should not be wound
    tightly since at the low temperatures encountered
    in the upper atmosphere the clock spring may
    snap. However, if the clock is wound an hour
    or so before release, it will be sufficiently
    relaxed by the time the low temperatures are
    reached.

(c) Check pressure of the marking pens. Too much
    pressure of the pens on the drum will introduce
    an error due to the frictional lag. When the
    drum is removed from the clock mechanism, and the
    pen lifter released, the stylus points should
    touch the clock housing lightly.

(d) Smoke the drum. A very thin, fine-grained carbon
    film should be deposited on the aluminum foil.
    The best result will be obtained by use of a
    bright yellow gas flame, although a kerosene flame
    gives a satisfactory coating. Solid or liquid
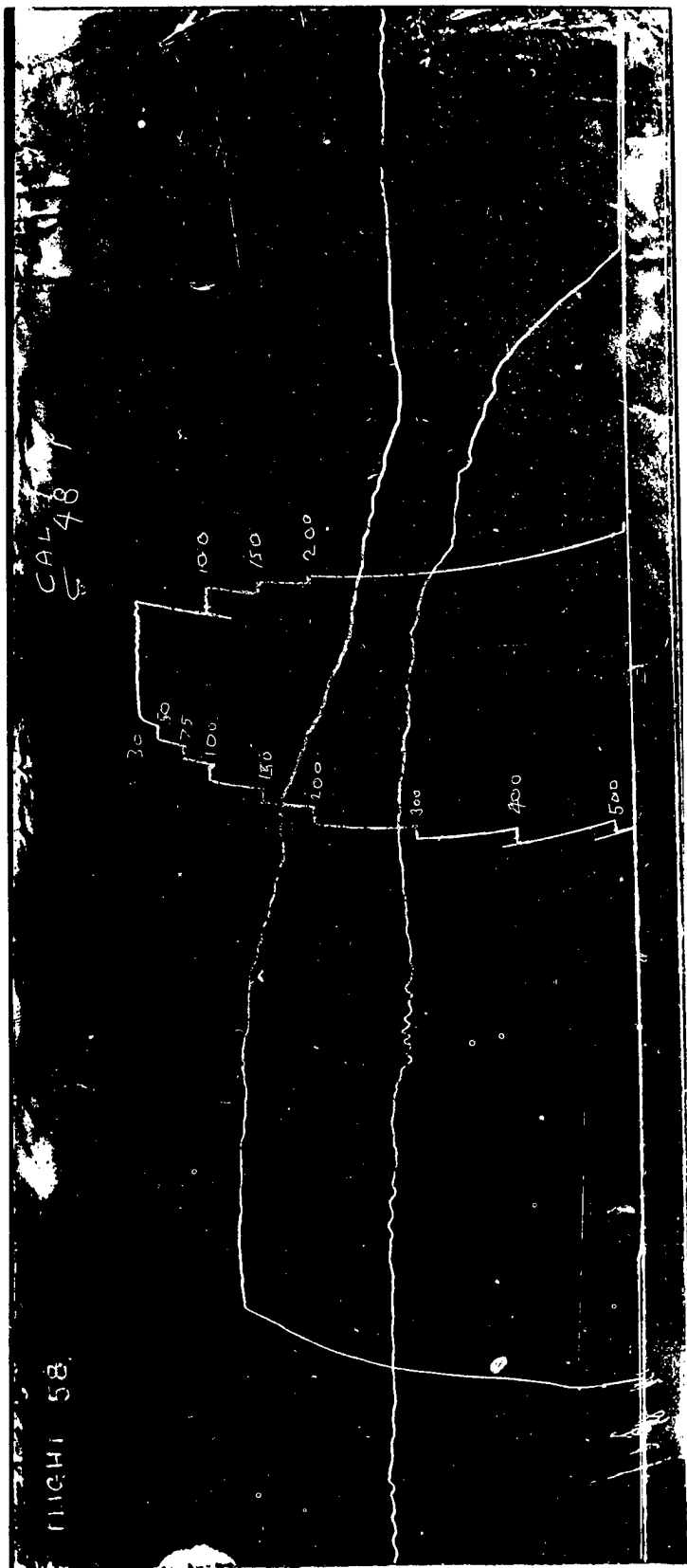
NYU BALLOON PROJECT
Barograph Record
FLIGHT 58
Released at Alamogordo,N.M. May 10-1948 2033M.S.T.,Recovered at
Val D'or, Quebec, Canada
(Orifice Ballast-Leak 300gm/hour)
Duration 24½ hours

Figure 36

fuels usually give a coating which is too coarse
grained and heavy. In smoking the drum a long
rod is used as a rotating axis. The drum is ro-
tated rapidly in the flame so as to prevent
overheating and oxidizing of the foil. The car-
bon should not be so thick as to obscure the
metallic appearance of the aluminum foil.

(e) Calibrate the barograph for pressure. The in-
strument is placed in a bell jar and the air
evacuated. The pressure is kept constant at a
number of pressures so that as the drum turns a
step, record is made on the smoked foil. Pressure
recording starts at about 500 millibars so the
first level in the calibration should be at that
value. At each level the pressure should be kept
constant for three to five minutes in order to
obtain a measurable line. Great care and consid-
erable practise are required to control the valves
of the vacuum system so that the pressure does
not change noticeably during each step.

The pressure steps at which the barograph is cali-
brated may be either at regular pressure intervals
or at the pressure values corresponding to regular
height intervals according to the standard at-
mosphere figures. The recommended steps are
listed below. If the balloon is not expected to
go to the higher altitudes, the calibration may
be stopped at correspondingly higher pressures.

Pressures	Standard Atmosphere Heights			
500 mb	466	mb corresponding	to	20,000 ft.
400 mb	300	mb "	"	30,000 ft.
300 mb	188.5	mb "	"	40,000 ft.
200 mb	117	mb "	"	50,000 ft.
150 mb	72.8	mb "	"	60,000 ft.
100 mb	45.3	mb "	"	70,000 ft.
50 mb	28.2	mb "	"	80,000 ft.
10 mb	17.5	mb "	"	90,000 ft.
	10.9	mb "	"	100,000 ft.

The temperature calibration may be made by recording
two widely spaced temperatures, such as room tem-
perature and the temperature of dry ice ($-78^{\circ}C$).
This calibration will be approximately a straight
line and, therefore, two points are sufficient
to plot the curve.

Immediately before the balloon release, when
the clock is wound and the pens lowered against
the drum, the pressure and temperature pens
should be tapped lightly so as to make short
marks and the time noted.

When the barograph is recovered the smoked foil
should be treated to preserve the record. A
solution of clear shellac diluted with about ten
times its volume of alcohol may be used. The
drum is immersed in the shellac and allowed to
dry thoroughly before further handling.

(f) Evaluation of the record. In evaluating the re-
cord heights of significant points are measured
vertically from the reference line. The pres-
sure calibration steps are measured first and plotted
on graph paper, vertical distance versus pressure
or altitude. Each significant point on the
flight trace is then measured and the corresponding
altitude determined from the calibration curve.

The same procedure is followed in evaluating the
temperature record, measuring from the reference
line.

The curvature of the record due to the motion
of the pens must be corrected for. Since the tem-
perature record covers a short vertical range, the
time correction may be neglected. Corrections
for curvature of the pressure record may be read
directly from Figure 37, which gives the correction
in inches as a function of the distance of the
point in question from the center of the record.

The final time correction is made to correlate
the temperature and pressure records. This may
be done by measuring the horizontal distance be-
tween the temperature and pressure marks as made
before release and correcting this amount for
vertical position. The rotation of the drum
is once in 12 hours and, therefore, the time-distance
relation may be computed by noting the total
length of record obtained in one revolution.
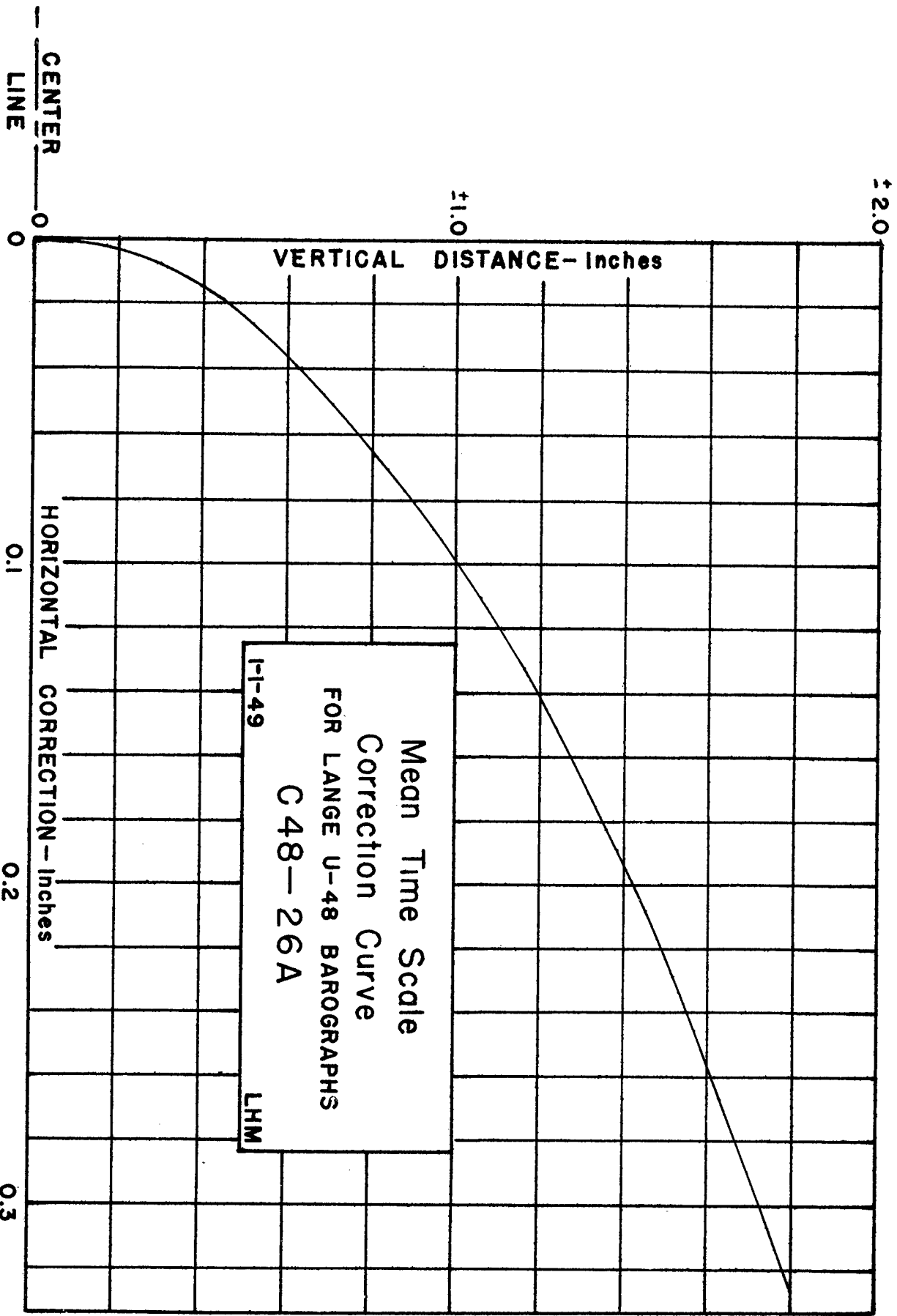
Mean Time Scale
Correction Curve
FOR LANGE U-48 BAROGRAPHS
C48-26A

1-1-49

LHM

VERTICAL DISTANCE-Inches

HORIZONTAL CORRECTION-Inches

FIG. 37

VIII. ANALYSIS

During and following the flight it is customary to analyze the behavior of the balloon. Two curves are usually drawn when data is available for their preparation. The first of these is a time-height curve which gives the altitude of the balloon at all times with respect to sea level. On this curve also it is customary to plot the temperature data and ballast flow data when such has been recorded. In some cases it has been found useful to plot a profile of the terrain over which the balloon is passing. The second diagram usually prepared is the trajectory of the balloon, and again it may be prepared with respect to the terrain over which the balloon was passing. That is to say, it is plotted on an aircraft map of the area, with positions and heights plotted every ten minutes. Figures 38 and 39 show sample plots.

IX. GENERAL MILLS 7-, 30-, AND 70-FOOT BALLOONS

The altitudes reached and loads which may be carried by the General Mills balloons other than the 20-foot cell are shown in Table 4, Appendix II. Graph 3, Appendix II may be used for interpolation of the tabulated values to give the relationship between floating altitude and gross load, and Graph 4 shows the altitude sensitivity at various heights. It has been assumed that helium is the lifting gas. Graph 1, Appendix II is useable for all of these balloons to determine the amount of free lift which is needed to give a desired rate of rise.

To launch a 7-foot balloon, it is not necessary to utilize the elaborate technique of the larger balloons. A can of sand is made to weigh the same amount as the required gross lift (equipment weight plus free lift), and attached to the load ring. Inflation from a single tank may be made inside any building with relatively large doors and when the balloon just lifts the inflation weights it may be attached to the equipment line, carried outdoors and released. In light winds the equipment may be released with a hand-over-hand paying out of the line. If there is too much wind for this method, the equipment is laid out downwind and the balloon released so as to pass over the pieces of gear and pick them up while rising.

A 7-foot balloon being inflated is seen in Figure 40. The appendix which is shown is made of a flattened 2-foot length of inflation tube, from a 20-foot balloon, without stiffeners. Such a balloon has been sustained with a fixed ballast leak

NYU BALLOON PROJECT
FLIGHT NO. 11

Released at Alamogordo, New Mexico
July 7, 1947
0508 MST

(Numerals on Curves Indicate Minutes After
Release.)

FIG. 38

Figure 38

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NYU BALLOON PROJECT FLIGHT 58

ESTIMATED TRAJECTORY

Estimated Duration – 24 1/2 Hours

FIG. 39

VAL D'OR
QUEBEC

Last Observed
Balloon Position

2033 MST
10 MAY 1948
ALAMOGORDO, N.M.
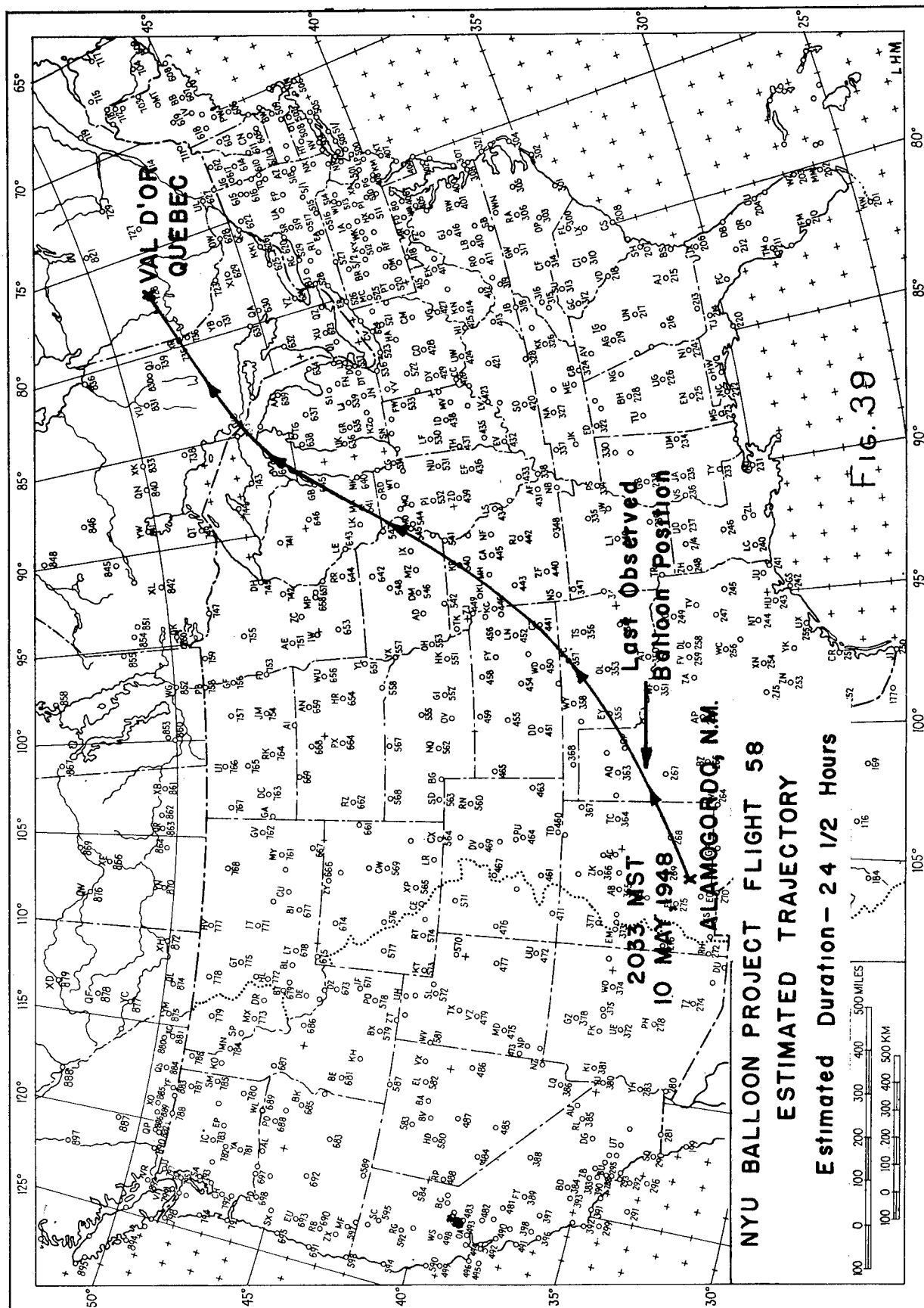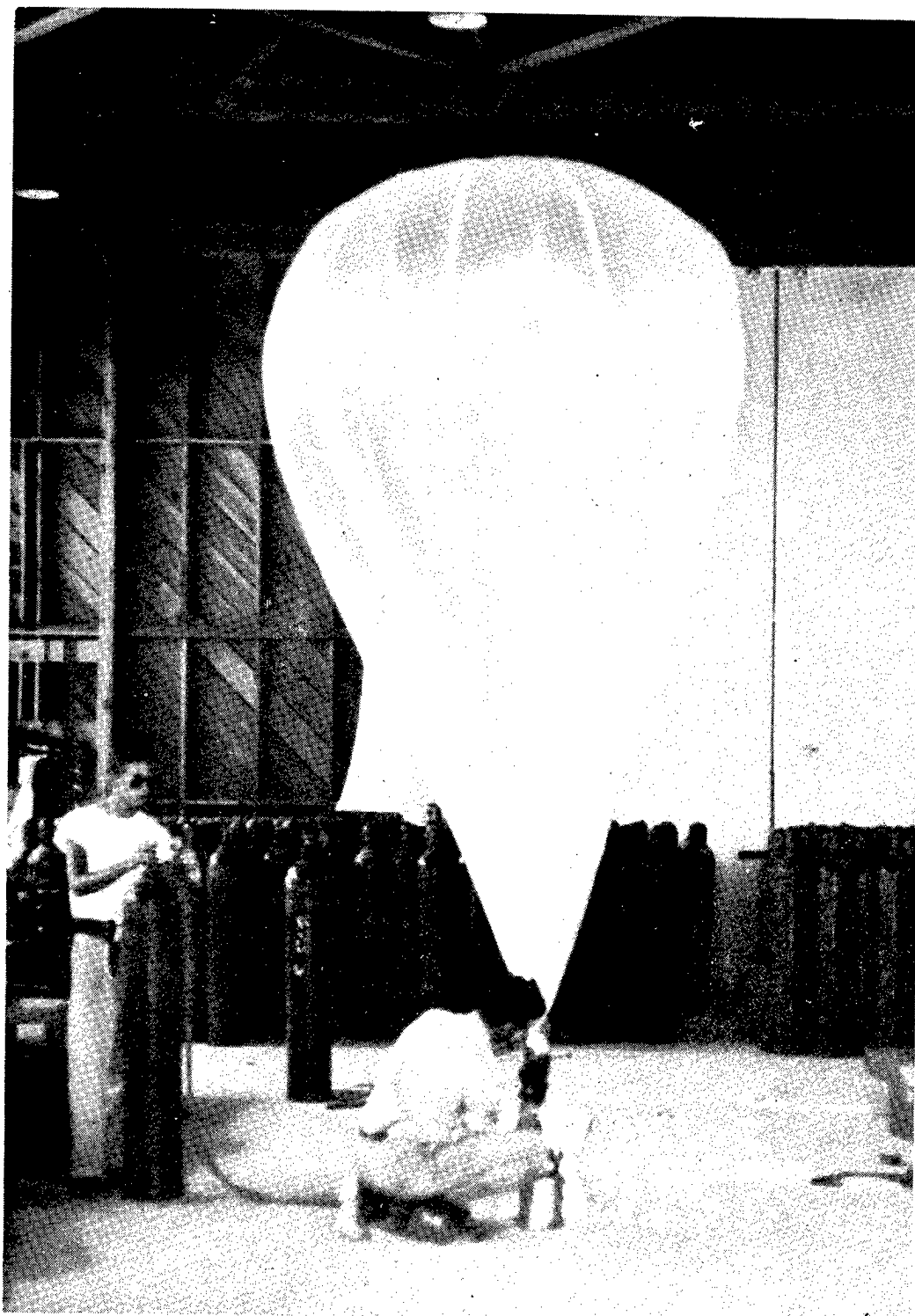
Figure 40
General Mills 7 foot
balloon being inflated.

of 170 grams per hour. A balloon of this type with no altitude control stayed aloft for more than two hours and after reaching ceiling, the altitude did not vary by more than 1500 feet while the balloon was within range of the observing station.

The preparation and launching techniques discussed for the 20-foot balloon apply also to the 30-foot cell. No further discussion is required for the 30-foot balloon.

The 70-foot balloon seen in Figures 41 and 42 is launched in the same manner as the 20-foot cell. A much larger amount of gas is required and since it is valved rapidly into the balloon, it has been found necessary to pass the gas through a heating coil to prevent it from reaching the balloon so adiabatically cooled as to be incapable of lifting the load. This heater is shown in Figure 43. Due to the large lift and area exposed to the wind at launching, the large cell may be dangerous if personnel attempt to hold the gear or act as anchors. If possible, all gear should be laid out downwind to be picked up from the ground by the balloon. The anchor should be a winch mounted on a truck which can move around the balloon so as to be downwind at launching.

Since the altitudes where the 70-foot balloons normally float are high in the stratosphere, the natural stability of the balloon in the temperature inversion keeps these cells up for a long period of time without ballast or other controls. One such flight fell slowly during a period of 75 hours and was still above 65,000 feet when the barograph record ended.
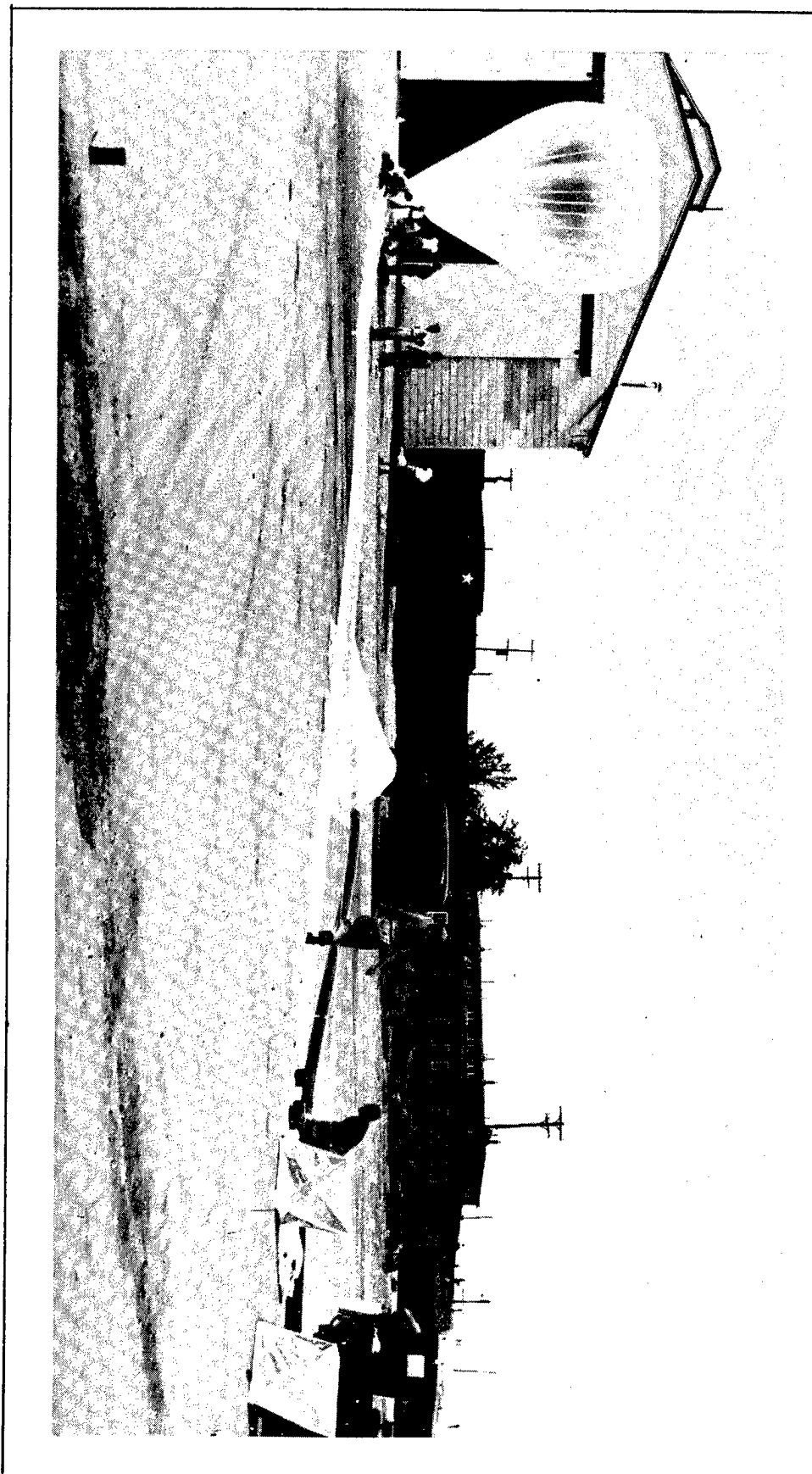
Figure 41
Inflation of 70 foot diameter
General Mills balloon.
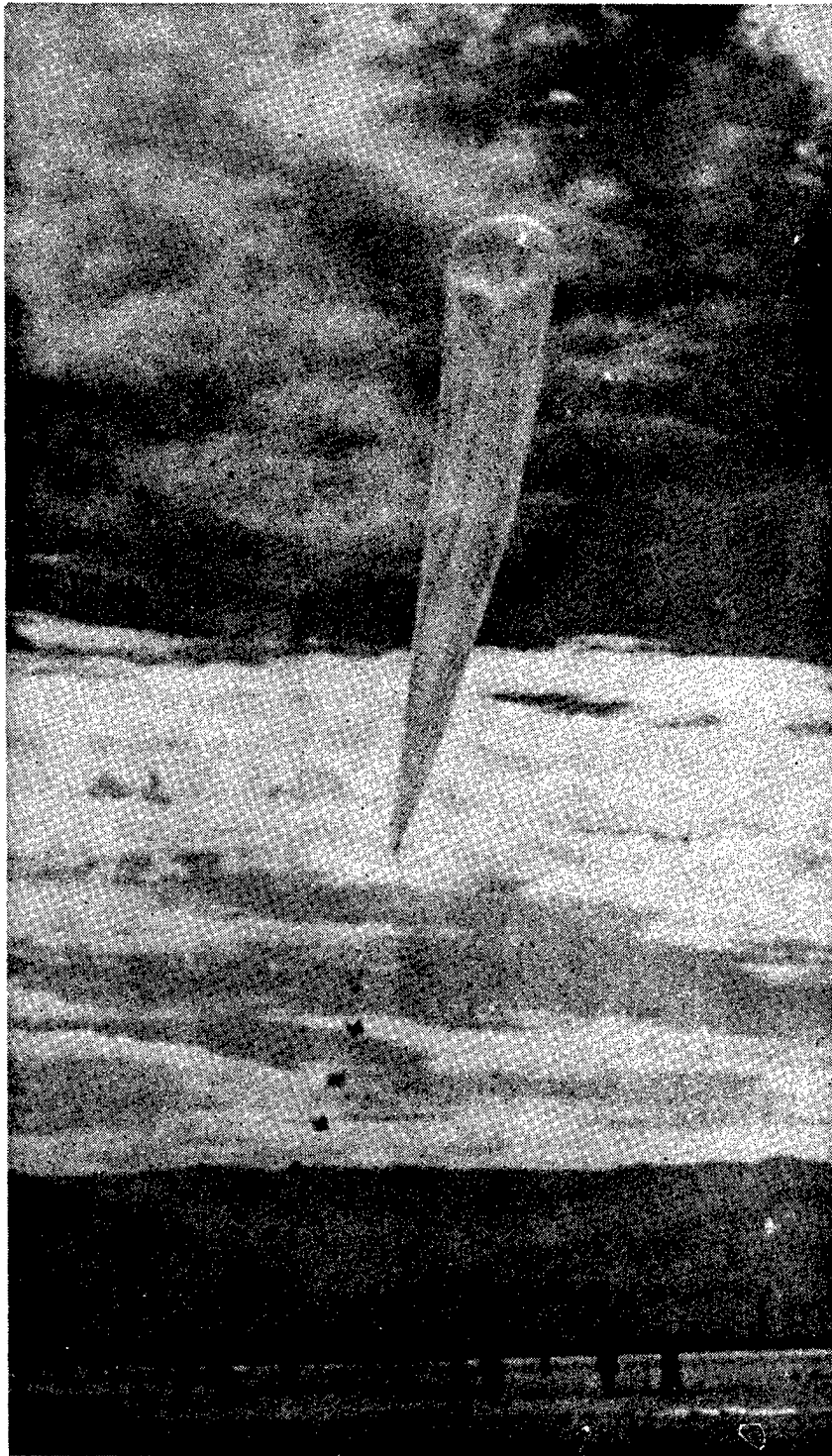
Figure 42
General Mills 70 foot balloon
being launched in a 5 knot wind.

Fig. 43

ASBESTOS CLOTH

DOUBLE COIL
MADE OF $\frac{5}{8}$" O.D.
COPPER TUBE

$13\frac{3}{8}$"

$5\frac{5}{8}$"

$\frac{3}{32}$"

COIL ASSEMBLY (SECTION)

METAL HOSE TO TANKS
HEATING COIL ASSEMBLY
DIAL THERMOMETER
ADAPTER
DEFLECTOR PLATE
WEED BURNER ON ALUMINUM SLED

SCALE 1:4

$23\frac{1}{2}$"
10"
6"
4"
$10\frac{1}{2}$"
3"
$\frac{5}{8}$"
$1\frac{1}{4}$"

BAFFLES

6"

$\frac{3}{64}$"
(SHEET METAL)

BRASS FITTING FOR THERMO-METER

FRAME MADE OF $\frac{1}{2}$×1 STEEL STRAP

$1\frac{1}{4}$" STANDARD BRASS PIPING

TOTAL WIDTH $8\frac{1}{4}$"

FLAME DEFLECTOR PLATE
(TO BE HOOKED ON FRAME)

4"
1"

4"
7"
16"

SUPPORTING FRAME

NYU BALLOON PROJECT

HELIUM HEATER

DATE		
7-22-48	ED48-71	

-78-

GLOSSARY

Altitude Sensitivity: The altitude gained by a balloon when its
                        load is reduced by one kilogram.

Balloon Inflation: Gas inflation to be given the balloon in
                        terms of initial lift of the balloon
                        (equals weight of equipment load plus free
                        lift plus allowance for gas losses before
                        launching).

Ceiling: The locus of pressure altitudes at which a
                        non-extensible balloon will float when gas
                        losses are slightly over-compensated for
                        by ballast losses.

Equipment Load: Weight of all equipment, rigging, and ballast
                        hung from the balloon shrouds not including
                        balloon or its integral parts.

Floor: The locus of altitudes at which a balloon will
                        float when lift losses are exactly compensated
                        for on a demand basis by ballast dropping.
                        In practice, this is determined by the opera-
                        tion of the automatic ballast release and
                        is some altitude below the ceiling.

Free Lift: Net lift of the balloon with the equipment
                        load attached.

Gross Lift: Lift of all of the gas in the balloon at re-
                        lease (equals weight of the balloon, equip-
                        ment load plus the free lift).

Gross Load: Load on the gas at release (balloon plus
                        equipment load weight).

Pressure Altitude: The altitude at which a non-extensible bal-
                        loon becomes fully inflated.

Pressure Height: The height above mean sea level as determined
                        from pressure measurements used in this work
                        with the N. A. C. A. Standard Atmosphere.

Appendix I

Table 1

BASIC EQUIPMENT FOR FIELD TRIPS
LAUNCHING OF 20' BALLOONS
WITH SIMPLE CONTROL GEAR

GROUND EQUIPMENT:	NYU Balloon Project Drawing No. or Figure No. in Operations Manual
1 ea. Set instructions (Operations Manual)	
2 ea. Elliptical shot bags (each filled with 100 # of shot)	ED-48-62
2 ea. 40 # Sand bags	ED-48-122A
4 ea. 40 # Sand bags	
1 ea. 40' x 6' Ground Cloth	
4 ea. Sheets polyethylene, .001" to .004", 4' x 4'	
1 ea. 5 Tank manifold with pressure gages and valve	Figure 26
1 ea. Rubber hose, 1" I.D., 10' long	
1 ea. Gas diffuser	ED-48-76A
2 ea. Rubber tubing $\frac{1}{2}$" bore, 1/8" wall, 8' long	
2 ea. Hose clamps, aeroseal, $1\frac{1}{4}$" I.D.	
3 ea. Hose ends for helium tanks	ED-48-80
1 ea. Box white chalk	
1 ea. Solution balance Fisher #2-100	
1 ea. Inflation nozzle, ML-196	
3 ea. Weems plotters	
1 ea. Set aircraft maps of area	
1 ea. Tool kit complete with 2 sheath knives, 50' cloth measuring tape, brass wire, 1" Mystic tape, volt ohmmeter, pliers, screwdrivers, inflation tools, flashlights, crescent wrenches,	

(Tool kit, cont'd.) soldering iron, compass, 2 open-end wrenches 1-1/8" x 1-1/4" openings, 14" pipe wrench, spanner for helium tank valves

2 ea. Theodolite ML-247 with tripod ML-78

2 ea. Recorder, Brush oscillograph or other

2 ea. Standby power units

2 ea. SCR-658 Radio direction finder
                or
    2 ea. Hammerlund Super-Pro receiver
    2 ea. Kytoon with spare bladders for antenna support
    2 ea. Captive balloon, Dewey & Almy N4

4 ea. Chronometers

4 ea. Clip boards

2 ea. Complete set of communication equipment
    Telephone account

    Wind screen, 30' x 20', Y-shaped, equipped with flood lights and anemometer   ED-49-3

FLIGHT GEAR:

2 to 5 Tanks helium

1 ea. General Mills 20' balloon (or other balloon to be used) plus spare

24 ea. Rolls acetate fiber scotch tape

3 ea. Appendix stiffeners (if appendix is to be used)   ED-48-95A

1 ea. 200' 500 # Test nylon line

1 ea. 100' 75 # Test linen twine

2 ea. 350 Gram balloon ML-131A (for wind sock)

5 to 10 Toggles or hooks

2 ea. Parachutes ML-132

1 ea. Banner, 3' x 6'   ED-48-56

4 ea. Data sheets

4 ea. Weight sheets

4 ea. Reward tags (English, Spanish or other
language)   Figure 21

2 ea. "Danger Fire" tags   Figure 20

2 ea. Other Danger tags as required

If Flight Termination gear is to be used:

    1 ea. Flight termination switch   ED-48-70A

    1 ea. Set rip rigging   ED-48-68A

    2 ea. Cannons   ED-49-5

    2 ea. Squibs Du Pont S-64 (treated for
    high altitude)

If fixed rate ballast release is to be used:

    1 ea. Orifice spinnerette, to give ballast
    flow of 250 gm/hr (.008" D.)   ED-48-75A

    1 Gallon ballast, compass fluid AN-C-116

    1 ea. Ballast reservoir (1 gallon capacity)   ED-48-79A

    1 ea. Filter 3" diameter, 325 x 325, phosphor
    bronze mesh   ED-48-54A

    4 feet Tubing (Tygon) $\frac{1}{2}$" bore

    6 inches Tubing (Tygon) 3/16" bore

    Metal beakers or rimless 1 qt. tin cans

    Metal funnel

Table 2

WEIGHT SHEET

Flight No._____   Date_____

                                                 Time_____

Balloon   Manufacturer_____Weight_____
          Number_____

Appendix or valve _____ _____

Shrouds . . . . ._____

Total Balloon Weight . . . . ._____

Launching Remnant . . . . ._____

Line Length . . . . ._____

1st Unit. Serial No. _____

          description _____ _____

Line   length _____ _____

2nd Unit. Serial No. _____

          description _____ _____

Line   length _____ _____

3d Unit. Serial No. _____

          description _____ _____

Line   length _____ _____

4th Unit. Serial No. _____

          description _____ _____

Drag chute _____ _____

Banner description _____ _____

Ballast assembly - description _____ _____

_____

_____

_____

Ballast . . . . ._____

Total Equipment Weight . . . . ._____

Gross Load . . . . ._____

RATE OF RISE AND MAXIMUM ALTITUDE COMPUTATIONS

Flight No._____   Date_____

                                        Time_____

_____

BALLOON INFLATION

Desired Rate of Rise .   .   .   .   _____ft./min.

Gross Load .   .   ._____grams

Free Lift - from Rise chart_____grams

Free Lift $= \dfrac{V}{412}\, 2_G^{2/3}$ _____grams

Equipment Weight_____grams

Desired Balloon Inflation = Free Lift + Equipment Total_____grams

Allowance for Leakage @ _____ gm/hr., _____hrs. waiting_____ grams

Actual balloon lift .   .   .   .   _____ "

AActual gross lift (Balloon lift & balloon wt.) .   .   .   .   .   _____ "

Number Helium tanks required at_____kg lift/full tank .   .   .   _____ tanks

Length balloon above shot bag .   .   .   .   _____ feet

_____

MAXIMUM ALTITUDE

Balloon Volume .   .   .   .   _____ cu. ft.

Helium 11.1	kg/mol

Gas Lift/mol .   .   .   .   Hydrogen 12.0   kg/mol

Molar Volume $=$ Balloon volume x gas lift/mol
                    gross load

                                        _____ cu. ft.

Maximum Altitude .   .   .   .   ._____ft. m.s.l.

Altitude Sensitivity .   .   .   .   .   .   ._____ft./kg.

BALLAST COMPUTATIONS FLIGHT #_____

Balloon Surface Diffusion $\begin{Bmatrix} \text{measured} \\ \text{estimated} \end{Bmatrix}$ gm/hr.   o/o Inflation _____o/o

Full balloon surface diffusion - balloon surface diffusion
(o/o Inflation)   2/3_____gm/hr.

Estimated full Balloon ceilin diffusion - F. B. Surface Diffusion
$x \dfrac{\text{Ceiling Pr.}}{\text{Surface Pr.}}$ _____gr/hr.

Description of Ballast Unit: (components, serial nos. Dimensions)

Amount of Ballast _____gm.

Initial flow, maximum head_____gm./min.

Maximum flow, maximum head_____gm./min.

Estimated Ballast duration $\dfrac{\text{Amount of ballast}}{\text{Full balloon celling diffusion}}$_____hrs.

Size Orifice used_____in.   Waiting time before release_____min.

Size Limiting Orifice used_____in.

Size filter used_____in.

Initial Head to valve or orifice_____in.

Final   "   "   "   "   "   _____in;

New York University
Research Division
Balloon Project

Supplementary Information for Flight No. _____

Release: Site_____ date _____ time_____

Encoded Sounding Data:

_____

Encoded Upper Winds

_____

Release Weather

_____

In-Flight Hourly Weather

_____

Train Sketch in Folder_____Films Sent Out_____

List Flight Records in Folder:

_____

Remarks

Checked by _____

Transmitter Performance for Flight No. _____

Release: Date _____ Time _____ Site _____

Transmitter Type and Serial No. _____
Batteries: Type and Number _____

Open Circuit Voltages:

Voltages Under Load:

Description of Pressure Unit

Description of Special Equipment

Reception at Station #2

Reception at Station #3

Critique

Appendix II

PRESSURE AND TEMPERATURE

IN THE N.A.C.A. STANDARD ATMOSPHERE

December 1948

Prepared   by

        Irwin Brill
        Research Assistant

        Balloon Project
        Research Division
        New York University

Source   Pressure from surface (0 feet) to 65,000 feet: taken from National Advisory Committee for Aeronautics Report #538, and corrected as noted below.

Pressure from 65,000 feet to 163,538 feet: taken from National Advisory Committee for Aeronautics Report #1200.

Temperatures at 1000-foot intervals, taken from National Advisory Committee for Aeronautics Reports #538 and 1200.

Geopotential
Assumptions   for pressure corrections:

0 feet to 30,000 feet based upon assumed constant geopotential.

30,000 feet to 65,000 feet corrected for geopotential, by approximate correction factors. (Taken from extrapolated curve of difference in feet, from 65,000 to 100,000 feet, between N.A.C.A. table #538 (uncorrected) and N.A.C.A. Technical Note #1200 (corrected).

35,000 feet to 163,538 feet, corrected for geopotential by National Advisory Committee for Aeronautics, Note #1200.

Accuracy   Surface to 30,000 feet = 15 feet, assuming constant geopotential.

30,000 feet to 65,000 feet	± 30 feet
65,000 feet to 100,000 feet	± 50 feet
100,000 feet to 120,000 feet	± 100 feet
120,000 feet to 135,000 feet	± 150 feet
135,000 feet to 163,538 feet	± 250 feet

Table 1

PRESSURE (MB) VERSUS HEIGHT (FEET)

MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.
.015	-47	27	969	1228	28	922	2593	29	875	4002	31
.014	-20	27	968	1256	28	921	2622	29	874	4033	31
L013.25	0	27	967	1284	28	920	2651	29	873	4064	31
L013	7	27	966	1312	28	919	2680	29	872	4095	31
L012	34	27	965	1340	28	918	2709	29	871	4126	31
L011	61	27	964	1368	28	917	2738	29	870	4157	31
L010	88	27	963	1396	28	916	2767	29	869	4188	31
L009	115	27	962	1424	28	915	2796	29	868	4219	31
L008	142	27	961	1452	28	914	2825	29	867	4250	31
L007	169	27	960	1481	29	913	2854	29	866	4281	31
L006	198	27	959	1510	29	912	2883	29	865	4312	31
L005	223	27	958	1539	29	911	2912	29	864	4343	31
L004	250	27	957	1568	29	910	2942	30	863	4374	31
L003	277	27	956	1597	29	909	2972	30	862	4405	31
L002	304	27	955	1626	29	908	3002	30	861	4436	31
L001	332	28	954	1655	29	907	3032	30	860	4467	31
L000	360	28	953	1684	29	906	3062	30	859	4498	31
999	388	28	952	1713	29	905	3092	30	858	4529	31
998	416	28	951	1742	29	904	3122	30	857	4560	31
997	444	28	950	1761	29	903	3152	30	856	4591	31
996	472	28	949	1790	29	902	3182	30	855	4622	31
995	500	28	948	1829	29	901	3212	30	854	4653	31
994	528	28	947	1858	29	900	3242	30	853	4684	31
993	556	28	946	1887	29	899	3272	30	852	4715	31
992	584	28	945	1916	29	898	3302	30	851	4746	31
991	612	28	944	1945	29	897	3332	30	850	4777	31
990	640	28	943	1974	29	896	3362	30	849	4808	31
989	668	28	942	2003	29	895	3392	30	848	4840	32
988	696	28	941	2032	29	894	3422	30	847	4872	32
987	724	28	940	2061	29	893	3452	30	846	4904	32
986	752	28	939	2090	29	892	3482	30	845	4936	32
985	780	28	938	2129	29	891	3512	30	844	4968	32
984	808	28	937	2158	29	890	3542	30	843	5000	32
983	836	28	936	2187	29	889	3572	30	842	5032	32
982	864	28	935	2216	29	888	3602	30	841	5064	32
981	892	28	934	2245	29	887	3632	30	840	5096	32
980	920	28	933	2274	29	886	3662	30	839	5128	32
979	948	28	932	2303	29	885	3692	30	838	5160	32
978	976	28	931	2332	29	884	3723	31	837	5192	32
977	1004	28	930	2361	29	883	3754	31	836	5224	32
976	1032	28	929	2390	29	882	3785	31	835	5256	32
975	1060	28	928	2419	29	881	3816	31	834	5288	32
974	1088	28	927	2448	29	880	3847	31	833	5320	32
973	1116	28	926	2477	29	879	3878	31	832	5352	32
972	1144	28	925	2506	29	878	3909	31	831	5384	32
971	1172	28	924	2535	29	877	3940	31	830	5416	32
970	1200	28	923	2564	29	876	3971	31	829	5448	32

MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.
828	5480	32	781	7026	34	734	8648	35	687	10358	37
827	5512	32	780	7060	34	733	8683	35	686	10395	37
826	5544	32	779	7094	34	732	8718	35	685	10433	38
825	5576	32	778	7128	34	731	8754	36	684	10471	38
824	5608	32	777	7162	34	730	8790	36	683	10509	38
823	5640	32	776	7196	34	729	8826	36	682	10547	38
822	5672	32	775	7230	34	728	8862	36	681	10585	38
821	5704	32	774	7264	34	727	8898	36	680	10623	38
820	5736	32	773	7298	34	726	8934	36	679	10661	38
819	5768	32	772	7332	34	725	8970	36	678	10699	38
818	5800	32	771	7366	34	724	9006	36	677	10737	38
817	5833	33	770	7400	34	723	9042	36	676	10775	38
816	5866	33	769	7434	34	722	9078	36	675	10813	38
815	5909	33	768	7468	34	721	9114	36	674	10851	38
814	5932	33	767	7502	34	720	9150	36	673	10889	38
813	5965	33	766	7536	34	719	9186	36	672	10927	38
812	5998	33	765	7570	34	718	9222	36	671	10965	38
811	6031	33	764	7604	34	717	9258	36	670	11003	38
810	6064	33	763	7638	34	716	9294	36	669	11041	38
809	6097	33	762	7672	34	715	9330	36	668	11079	38
808	6130	33	761	7706	34	714	9366	36	667	11117	38
807	6163	33	760	7740	34	713	9402	36	666	11155	38
806	6196	33	759	7774	34	712	9438	36	665	11193	38
805	6229	33	758	7808	34	711	9474	36	664	11231	38
804	6262	33	757	7843	35	710	9510	36	663	11270	39
803	6295	33	756	7878	35	709	9546	36	662	11309	39
802	6328	33	755	7913	35	708	9582	36	661	11348	39
801	6361	33	754	7948	35	707	9618	36	660	11387	39
800	6394	33	753	7983	35	706	9655	37	659	11426	39
799	6427	33	752	8018	35	705	9692	37	658	11465	39
798	6460	33	751	8053	35	704	9729	37	657	11504	39
797	6493	33	750	8088	35	703	9766	37	656	11543	39
796	6526	33	749	8123	35	702	9803	37	655	11582	39
795	6559	33	748	8158	35	701	9840	37	654	11621	39
794	6592	33	747	8193	35	700	9877	37	653	11660	39
793	6625	33	746	8228	35	699	9914	37	652	11699	39
792	6658	33	745	8263	35	698	9951	37	651	11738	39
791	6691	33	744	8298	35	697	9988	37	650	11777	39
790	6724	33	743	8333	35	696	10025	37	649	11816	39
789	6757	33	742	8368	35	695	10062	37	648	11855	39
788	6790	33	741	8403	35	694	10099	37	647	11894	39
787	6823	33	740	8438	35	693	10136	37	646	11933	39
786	6856	33	739	8473	35	692	10173	37	645	11972	39
785	6890	33	738	8508	35	691	10210	37	644	12011	39
784	6924	34	737	8543	35	690	10247	37	643	12051	40
783	6958	34	736	8578	35	689	10284	37	642	12091	40
782	6992	34	735	8613	35	688	10321	37	641	12131	40

MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.
640	12171	40	592	14130	42	543	16270	45	494	18574	49
639	12211	40	591	14172	42	542	16315	45	493	18623	49
638	12251	40	590	14214	42	541	16360	45	492	18672	49
637	12291	40	589	14256	42	540	16405	45	491	18721	49
636	12331	40	588	14298	42	539	16451	46	490	18770	49
635	12371	40	587	14341	43	538	16497	46	489	18819	49
634	12411	40	586	14384	43	537	16543	46	488	18868	49
633	12451	40	585	14427	43	536	16589	46	487	18917	49
632	12491	40	584	14470	43	535	16635	46	486	18966	49
631	12531	40	583	14513	43	534	16681	46	485	19015	49
630	12571	40	582	14556	43	533	16727	46	484	19065	50
629	12611	40	581	14599	43	532	16773	46	483	19115	50
628	12651	40	589	14642	43	531	16819	46	482	19165	50
627	12691	40	579	14685	43	530	16865	46	481	19215	50
626	12731	40	578	14728	43	529	16911	46	480	19265	50
625	12771	40	577	14771	43	528	16957	46	479	19315	50
624	12811	40	576	14814	43	527	17003	46	478	19365	50
623	12851	40	575	14857	43	526	17049	46	477	19415	50
622	12891	40	574	14900	43	525	17095	46	476	19465	50
621	12931	40	573	14943	43	524	17141	46	475	19515	50
620	12971	40	572	14986	43	523	17188	47	474	19565	50
619	13012	40	571	15029	43	522	17235	47	473	19616	51
618	13053	41	570	15072	43	521	17282	47	472	19667	51
617	13094	41	569	15115	43	520	17329	47	471	19718	51
616	13135	41	568	15158	43	519	17376	47	470	19769	51
615	13176	41	567	15202	44	518	17423	47	469	19820	51
614	13217	41	566	15246	44	517	17470	47	468	19871	51
613	13258	41	565	15290	44	516	17517	47	467	19922	51
612	13299	41	564	15334	44	515	17564	47	466	19973	51
611	13340	41	563	15378	44	514	17611	47	465	20024	51
610	13381	41	562	15422	44	513	17658	47	464	20075	51
609	13422	41	561	15466	44	512	17705	47	463	20127	52
608	13463	41	560	15510	44	511	17752	47	462	20179	52
607	13504	41	559	15554	44	510	17800	48	461	20231	52
606	13545	41	558	15598	44	509	17848	48	460	20283	52
605	13586	41	557	15642	44	508	17896	48	459	20335	52
604	13627	41	556	15686	44	507	17944	48	458	20387	52
603	13668	41	555	15730	45	506	17992	48	457	20439	52
602	13710	42	554	15775	45	505	18040	48	456	20491	52
601	13752	42	553	15820	45	504	18088	48	455	20543	52
600	13794	42	552	15865	45	503	18136	48	454	20595	52
599	13836	42	551	15910	45	502	18184	48	453	20647	52
598	13878	42	550	15955	45	501	18232	48	452	20699	52
597	13920	42	549	16000	45	500	18280	48	451	20751	52
596	13962	42	548	16045	45	499	18329	49	450	20803	52
595	14004	42	547	16090	45	498	18378	49	449	20856	53
594	14046	42	546	16135	45	497	18427	49	448	20909	53
593	14088	42	545	16180	45	496	18476	49	447	20962	53
			544	16225	45	495	18525	49	446	21015	53

MB	ALT.	DIF.	MB	ALT.	DIF.	MB.	ALT.	DIF.	MB	ALT.	DIF.
445	20543	53	397	23741	58	349	26684	64	301	29989	74
444	21122	54	396	23799	58	348	26748	64	300	30061	74
443	21176	54	395	23857	58	347	26812	64	299	30139	76
442	21230	54	394	23915	58	346	26878	66	298	30217	76
441	21284	54	393	23973	58	345	26944	66	297	30295	76
440	21338	54	392	24031	58	344	27010	66	296	30373	76
439	21392	54	391	24090	60	343	27076	66	295	30451	76
438	21446	54	390	24150	60	342	27142	66	294	30529	78
437	21500	54	389	24210	60	341	27208	66	293	30607	78
436	21554	54	388	24270	60	340	27274	66	292	30685	78
435	21608	54	387	24330	60	339	27340	66	291	30763	78
434	21662	54	386	24390	60	338	27406	66	290	30841	78
433	21716	54	385	24450	60	337	27472	66	289	30919	78
432	21770	54	384	24510	60	336	27538	66	288	30977	78
431	21824	54	383	24570	60	335	27604	66	287	31075	78
430	21878	54	382	24630	.60	334	27670	66	286	31153	78
429	21932	54	381	24690	60	333	27738	68	285	31231	78
428	21986	54	380	24750	60	332	27806	68	284	31309	78
427	22040	54	379	24810	60	331	27874	68	283	31387	78
426	22095	55	378	24870	60	330	27942	68	282	31465	78
425	22151	56	377	24930	60	329	28010	68	281	31544	80
424	22207	56	376	24990	60	328	28078	68	280	31624	80
423	22263	56	375	25050	60	327	28146	68	279	31704	80
422	22319	56	374	25112	62	326	28214	68	278	31784	80
421	22375	56	373	25174	62	325	28282	68	277	31864	80
420	22431	56	372	25236	62	324	28350	68	276	31944	80
419	22487	56	371	25298	62	323	28418	68	275	32024	80
418	22543	56	370	25360	62	322	28487	69	274	32104	80
417	22599	56	369	25422	62	321	28557	70	273	32184	80
416	22655	56	368	25484	62	320	28627	70	272	32264	80
415	22711	56	367	25546	62	319	28697	70	271	32344	80
414	22767	56	366	25608	62	318	28767	70	270	32424	80
413	22823	56	365	25670	62	317	28837	70	269	32504	80
412	22879	56	364	25732	62	316	28909	72	268	32584	80
411	22935	56	363	25794	62	315	28981	72	267	32264	80
410	22991	56	362	25856	62	314	29053	72	266	32744	80
409	23047	56	361	25918	62	313	29125	72	265	32824	80
408	23103	56	360	25980	62	312	29197	72	264	32904	80
407	23161	58	359	26044	64	311	29269	72	263	32984	80
406	23219	58	358	26108	64	310	29341	72	262	32064	80
405	23277	58	357	26172	64	309	29413	72	261	33144	80
404	23335	58	356	26236	64	308	29485	72	260	33226	82
403	23393	58	355	26300	64	307	29557	74	259	33308	82
402	23451	58	354	26364	64	306	29629	74	258	33390	82
401	23509	58	353	26428	64	305	29701	74	257	33472	82
400	23567	58	352	26492	64	304	29773	74	256	33554	82
399	23625	58	351	26556	64	303	29845	74	255	33638	84
398	23683	58	350	26620	64	302	29917	74	254	33722	84

MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.
253	33806	84	204	38338	102	155	44110	136	106	52099	196
252	33890	84	203	38440	102	154	44246	136	105	52299	200
251	33974	84	202	38544	104	153	44382	136	104	52499	200
250	34060	86	201	38648	104	152	44520	138	103	52701	204
249	34146	86	200	38752	104	151	44660	140	102	52905	204
248	34232	86	199	38858	106	150	44800	140	100	53316	208
247	34318	86	198	38964	106	149	44940	140	△ MB= .50		
246	34404	86	197	39070	106	148	45081	142	99.50	53421	105
245	34490	86	196	39178	108	147	45225	144	99.00	53526	105
244	34576	86	195	39286	108	146	45369	144	98.50	53631	105
243	34662	86	194	39394	108	145	45513	144	98.00	53741	110
242	34749	88	193	39502	108	144	45657	144	97.50	53851	110
241	34837	88	192	39612	110	143	45804	146	97.00	53961	110
240	34925	88	191	39721	110	142	45952	148	96.50	54071	110
239	35013	88	190	39832	112	141	46100	148	96.00	54181	110
238	35101	88	189	39944	112	140	46248	148	95.50	54291	110
237	35189	88	188	40056	112	139	46400	150	95.00	54401	110
236	35277	88	187	40168	112	138	46552	152	94.50	54511	110
235	35367	90	186	40280	112	137	46704	152	94.00	54621	110
234	35457	90	185	40392	112	136	46856	152	93.50	54733	115
233	35547	90	184	40506	116	135	47012	156	93.00	54848	115
232	35637	90	183	40622	116	134	47168	156	92.50	54963	115
231	35727	90	182	40738	116	133	47324	156	92.00	55078	115
230	35819	90	181	40854	116	132	47484	160	91.50	55433	115
229	35911	92	180	40970	116	131	47644	160	90.00	55548	115
228	36003	92	179	41086	116	130	47804	160	89.50	55653	115
227	36095	92	178	41202	118	129	47968	164	89.00	55770	120
226	36187	92	177	41321	120	128	48132	164	88.50	55890	120
225	36281	94	176	41441	120	127	48296	164	88.00	56010	120
224	36375	94	175	41561	120	126	48464	168	87.50	56130	120
223	36469	94	174	41681	120	125	48632	168	87.00	56250	120
222	36563	94	173	41801	120	124	48800	168	86.50	56370	120
221	36658	96	172	41921	120	123	48969	172	86.00	56491	120
220	36754	96	171	42044	124	122	49141	172	85.50	56616	125
219	36850	96	170	42168	124	121	49313	172	85.00	56741	125
218	36946	96	169	42292	124	120	49488	176	84.50	56866	125
217	37042	96	168	42416	124	119	49664	176	84.00	56991	125
216	37138	98	167	42541	128	118	49840	176	83.50	57116	125
215	37236	98	166	42669	128	117	50018	180	83.00	57241	125
214	37334	98	165	42797	128	116	50198	180	82.50	57366	125
213	37432	98	164	42925	128	115	50381	184	82.00	57495	130
212	37530	98	163	43053	128	114	50565	184	81.50	57625	130
211	37630	100	162	43181	128	113	50752	188	81.00	57755	130
210	37730	100	161	43311	132	112	50940	188	80.50	57885	130
209	37830	100	160	43443	132	111	51129	190	80.00	58015	130
208	37930	100	159	43575	132	110	51321	192	79.50	58145	130
207	38032	100	158	43707	132	109	51513	192	79.00	58279	135
206	38134	102	157	43839	132	108	51707	196	78.50	58414	135
205	38236	102	156	43974	134	107	51903	196	78.00	58549	135

MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF
77.50	58684	135	52.50	66884	200	27.50	80502	380	20.60	86606	102
77.00	58819	135	52.00	67086	205	27.00	80892	390	20.50	86708	102
76.50	58959	140	51.50	67291	205	26.50	81284	400	20.40	86812	104
76.00	59099	140	51.00	67499	210	26.00	81684	410	20.30	86916	104
75.50	59239	140	50.50	67709	210	25.50	82090	420	20.20	87020	104
75.00	59379	140	50.00	67922	215	$\triangle P = .1mb$			20.10	87124	104
74.50	59519	140	49.50	68137	215	25.00	82510	84	20.00	87228	104
74.00	59659	140	49.00	68352	215	24.90	82596	86	19.90	87334	106
73.50	59799	140	48.50	68567	215	24.80	82682	86	19.80	87440	106
73.00	59943	145	48.00	68782	215	24.70	82768	86	19.70	87546	106
72.50	60088	145	47.50	68997	220	24.60	82854	86	19.60	87654	108
72.00	60233	145	47.00	69207	220	24.50	82940	86	19.50	87762	108
71.50	60378	145	46.50	69432	225	24.40	83026	86	19.40	87870	108
71.00	60527	150	46.00	69669	230	24.30	83112	86	19.30	87978	108
70.50	60677	150	45.50	69899	230	24.20	83200	88	19.20	28088	110
70.00	60827	150	45.00	70132	235	24.10	83288	88	19.10	88198	110
69.50	60977	150	44.50	70367	240	24.00	83376	88	19.00	88308	110
69.00	61131	155	44.00	70607	240	23.90	83464	88	18.90	88418	110
68.50	61286	155	43.50	70848	245	23.80	83552	88	18.80	88532	114
68.00	61441	155	43.00	71093	245	23.70	83640	88	18.70	88646	114
67.50	61596	155	42.50	71338	250	23.60	83730	90	18.60	88760	114
67.00	61751	155	42.00	71585	250	23.50	83820	90	18.50	88874	114
66.50	61908	160	41.50	71835	255	23.40	83910	90	18.40	88988	114
66.00	62068	160	41.00	72087	255	23.30	84000	90	18.30	89102	114
65.50	62228	160	40.50	72346	260	23.20	84092	92	18.20	89216	114
65.00	62388	160	40.00	72608	265	23.10	84184	92	18.10	89330	114
64.50	62551	165	39.50	72873	270	23.00	84276	92	18.00	89448	118
64.00	62716	165	39.00	73141	270	22.90	84368	92	17.90	89566	118
63.50	62881	165	38.50	73411	275	22.80	84462	94	17.80	89684	118
63.00	63047	170	38.00	73685	275	22.70	84556	94	17.70	89802	118
62.50	63217	170	37.50	73966	280	22.60	84650	94	17.60	89920	118
62.00	63387	170	37.00	74243	285	22.50	84744	94	17.50	90039	118
61.50	63557	170	36.50	74531	290	22.40	84838	94	17.40	90160	122
61.00	63727	170	36.00	74823	295	22.30	84932	94	17.30	90282	122
60.50	63899	175	35.50	75120	300	22.20	84028	96	17.20	90404	122
60.00	64074	175	35.00	75420	305	22.10	84124	96	17.10	90526	122
59.50	64249	175	34.50	75725	310	22.00	85220	96	17.00	90648	122
59.00	64429	180	34.00	76032	310	21.90	85316	96	16.90	90774	126
58.50	64609	180	33.50	76344	315	21.80	85412	96	16.80	90900	126
58.00	64789	180	33.00	76660	320	21.70	85508	96	16.70	91026	126
57.50	64970	185	32.50	76980	325	21.60	85606	98	16.60	91152	126
57.00	65155	185	32.00	77304	330	21.50	85704	98	16.50	91278	126
56.50	65340	185	31.50	77634	335	21.40	85802	98	16.40	91408	130
56.00	65525	190	31.00	77972	340	21.30	85900	98	16.30	91538	130
55.50	65715	190	30.50	78314	350	21.20	86000	100	16.20	91668	130
55.00	65905	190	30.00	78664	360	21.10	86100	100	16.10	91798	130
54.50	66095	195	29.50	79022	360	21.00	86200	100	16.00	91928	130
54.00	66290	195	29.00	79382	365	20.90	86300	100	15.90	92064	136
53.50	66485	200	28.50	79748	370	20.80	86402	102	15.80	92200	136
53.00	66684	200	28.00	80122	380	20.70	86504	102	15.70	92336	136

MB	ALT.	DIF.	MB	ALT.	DIF.	MB	ALT.	DIF.
15.60	92472	136	10.60	100634	198	5.60	114578	432
15.50	92608	136	10.50	100832	198	5.50	115010	432
15.40	92744	136	10.40	101030	198	5.40	115442	432
15.30	92886	142	10.30	101240	210	5.30	115874	432
15.20	93028	142	10.20	101450	210	5.20	116338	464
15.10	93170	142	10.10	101660	210	5.10	116802	464
15.00	93312	142	10.00	101870	210	5.00	117266	464
14.90	93454	142	9.90	102080	210	4.90	117730	464
14.80	93596	142	9.80	102304	224	4.80	118194	464
14.70	93738	142	9.70	102528	224	4.70	118724	530
14.60	93880	142	9.60	102752	224	4.60	119254	530
14.50	94022	142	9.50	102976	224	4.50	119784	530
14.40	94164	142	9.40	103200	224	4.40	120352	568
14.30	94306	142	9.30	103424	224	4.30	120920	568
14.20	94454	148	9.20	103648	224	4.20	121488	568
14.10	94602	148	9.10	103872	224	4.10	122056	568
14.00	94750	148	9.00	104096	224	4.00	122696	640
13.90	94898	148	8.90	104342	246	3.90	123336	640
13.80	95046	148	8.80	104588	246	3.80	123976	640
13.70	95200	154	8.70	104834	246	3.70	124672	696
13.60	95360	160	8.60	105080	246	3.60	125368	696
13.50	95520	160	8.50	105326	246	3.50	126064	696
13.40	95680	160	8.40	105572	246	3.40	126858	794
13.30	95840	160	8.30	105818	246	3.30	127652	794
13.20	96000	160	8.20	106064	246	3.20	128464	812
13.10	96160	160	8.10	106339	275	3.10	129276	812
13.00	96320	160	8.00	106614	275	3.00	130088	812
12.90	96480	160	7.90	106889	275	2.90	131032	944
12.80	96648	168	7.80	107164	275	2.80	131976	944
12.70	96816	168	7.70	107439	275	2.70	132984	1008
12.60	96984	168	7.60	107714	275	2.60	133992	1008
12.50	97152	168	7.50	107989	275	2.50	135074	1082
12.40	97320	168	7.40	108296	307	2.40	136156	1082
12.30	97498	178	7.30	108603	307	2.30	137438	1282
12.20	97676	178	7.20	108910	307	2.20	138720	1282
12.10	97854	178	7.10	109217	307	2.10	140002	1282
12.00	98032	178	7.00	109524	307	2.00	141462	1460
11.90	98210	178	6.90	109831	307	1.90	142922	1460
11.80	98388	178	6.80	110138	307	1.80	144382	1460
11.70	98566	178	6.70	110482	344	1.70	146182	1800
11.60	98744	178	6.60	110828	346	1.60	148062	1880
11.50	98922	178	6.50	111174	346	1.50	150040	1978
11.40	99100	178	6.40	111520	346	1.40	152176	2136
11.30	99288	188	6.30	111866	346	1.30	154384	2208
11.20	99476	188	6.20	112246	380	1.20	156792	2408
11.10	99664	188	6.10	112626	380	1.10	160040	3248
11.00	99852	188	6.00	113006	380	1.00	163538	3498
10.90	100040	188	5.90	113386	380			
10.80	100238	198	5.80	113766	380			
10.70	100436	198	5.70	114146	380			

Table 2

TEMPERATURE IN N.A.C.A. STANDARD ATMOSPHERE

Altitude	Temp.(°C)	Altitude	Temp.(°C)	Altitude	Temp.(°C)
0	15			96,000	-55
1,000	13	48,000	-55	97,000	-55
2,000	11	49,000	-55	98,000	-55
3,000	9.1	50,000	-55	99,000	-55
4,000	7.1	51,000	-55	100,000	-55
5,000	5.1	52,000	-55	102,000	-55
6,000	3.1	53,000	-55	104,000	-55
7,000	1.1	54,000	-55	104,987	-55
8,000	- 0.8	55,000	-55	106,000	-52.9
9,000	- 2.8	56,000	-55	108,000	-48.5
10,000	- 4.8	57,000	-55	110,000	-43.9
11,000	- 6.8	58,000	-55	112,000	-39.5
12,000	- 8.8	59,000	-55	114,000	-35.0
13,000	-10.8	60,000	-55	116,000	-30.6
14,000	-12.7	61,000	-55	118,000	-26.1
15,000	-14.7	62,000	-55	120,000	-21.6
16,000	-16.7	63,000	-55	122,000	-17.1
17,000	-18.7	54,000	-55	124,000	-12.7
18,000	-20.7	65,000	-55	126,000	- 8.2
19,000	-22.6	66,000	-55	128,000	- 3.7
20,000	-24.6	67,000	-55	130,000	+ .72
21,000	-26.6	68,000	-55	132,000	+ 5.2
22,000	-28.6	69,000	-55	134,000	+ 9.7
23,000	-30.6	70,000	-55	136,000	+14.2
24,000	-32.5	71,000	-55	138,000	+18.6
25,000	-34.5	72,000	-55	140,000	+23.1
26,000	-36.5	73,000	-55	142,000	+27.6
27,000	-38.5	74,000	-55	144,000	+32.1
28,000	-40.5	75,000	-55	146,000	+36.5
29,000	-42.5	76,000	-55	148,000	+41.0
30,000	-44.4	77,000	-55	150,000	+45.5
31,000	-46.4	78,000	-55	152,000	+50.0
32,000	-48.4	79,000	-55	154,000	+54.4
33,000	-50.4	80,000	-55	156,000	+58.9
34,000	-52.4	81,000	-55	158,000	+63.4
35,000	-54.3	82,000	-55	160,000	+67.8
35,332	-55	83,000	-55	162,000	+72.3
36,000	-55	84,000	-55	164,000	+76.8
37,000	-55	85,000	-55		
38,000	-55	86,000	-55		
39,000	-55	87,000	-55		
40,000	-55	88,000	-55		
41,000	-55	89,000	-55		
42,000	-55	90,000	-55		
43,000	-55	91,000	-55		
44,000	-55	92,000	-55		
45,000	-55	93,000	-55		
46,000	-55	94,000	-55		
47,000	-55	95,000	-55		

Table 3

Table of flows in gm/hr. from "Spinnerette Orifices"

dia. (in inches)	Q (actual) in gm/hr.			
	at 24 Hd.	at 22" Hd.	at 20" Hd.	at 18" Hd.
.003	35	33.5	32	30.5
.004	62.8	60	57	54.5
.005	97.5	93.5	88.8	84.5
.006	141	134	128	122
.007	192	184	175	166
.008	251	241	229	217
.009	317	303	289	274
.010	392	375	358	340
.011	474	453	433	410
.012	564	540	515	488

$$Q \text{ (actual) gm/hr.} = C_d \text{ (dia.")}^2 \text{ (hd.")}^{\frac{1}{2}} \times 1.003 \times 10^6$$
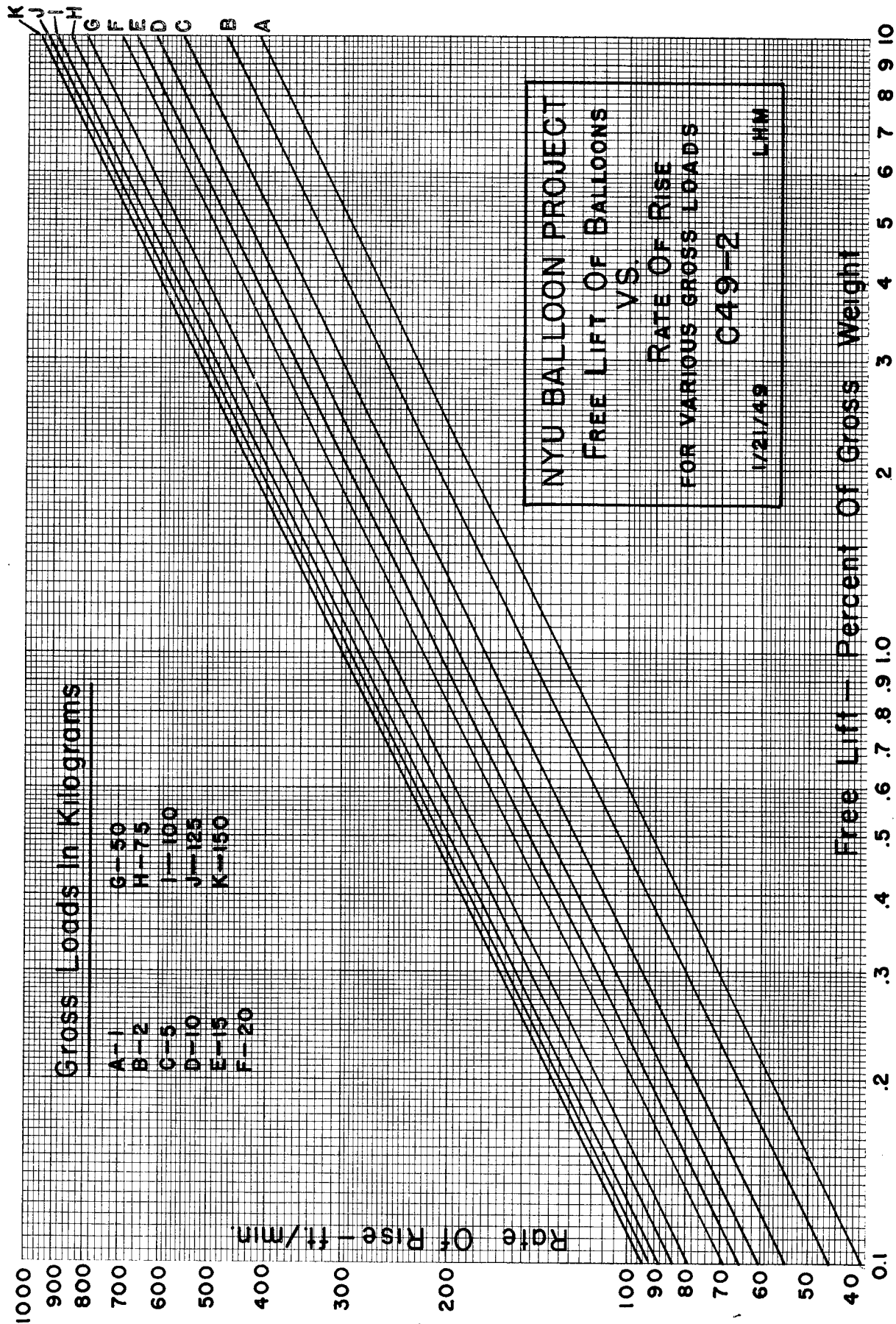
(C_d varies from .78 to .82)

C_d (mean) $\doteq$ .80 (used above)

$$\frac{Q_1}{Q_2} = \left(\frac{hd._1}{hd._2} \right)^{\frac{1}{2}}$$
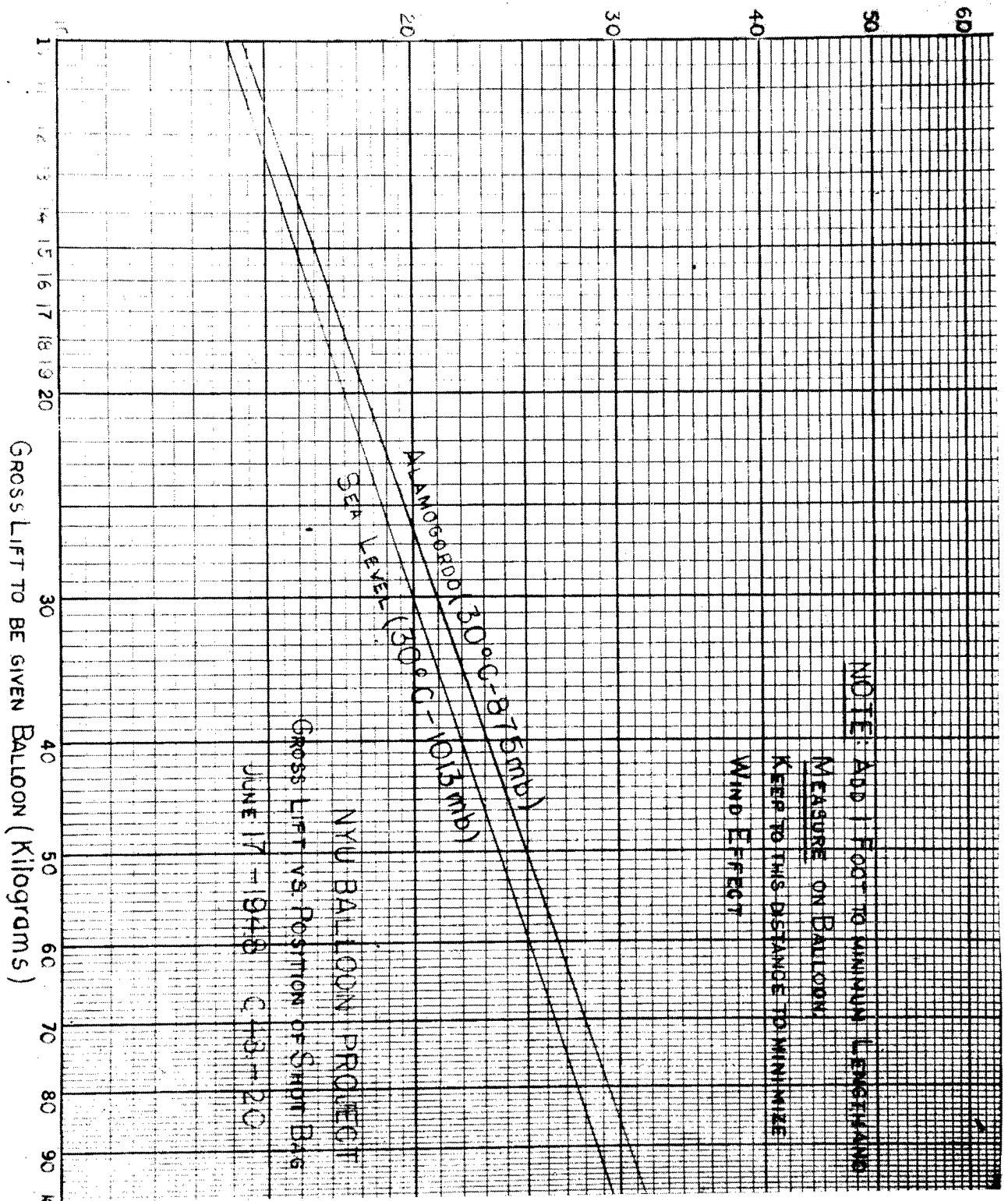
Table 4

BALLOON DATA

General Mills Nominal Diameter ft.	Actual Volume cu.ft.	Balloon Weight kg.	Estimated Gross Load Limit kg.	Altitude Range ft.
7	200	0.6	1.5 to 5	38,000 to 0
20	4300	3.8 to 5.0	7 to 36	68,000 to 37,000
30	12,700	8.9	12 to 60	82,000 to 50,000
70	200,000	41 to 54	50 to 175	110,000 to 84,000

NYU BALLOON PROJECT

FREE LIFT OF BALLOONS
VS
RATE OF RISE
FOR VARIOUS GROSS LOADS

C49-2

1/21/49   LHM

Free Lift — Percent Of Gross Weight

Rate Of Rise — ft/min.

Gross Loads In Kilograms

A — 1
B — 2
C — 5
D — 10
E — 15
F — 20

G — 50
H — 75
I — 100
J — 125
K — 150

Minimum Length of GM Balloon above Shot Bag in Feet

Gross Lift to be given Balloon (Kilograms)

Alamogordo (30°C - B.76 mb)

Sea Level (30°C - 1013 mb)

NOTE: Add 1 Foot to minimum length and
Measure on Balloon
Keep to this distance to minimize
Wind Effect

NYU BALLOON PROJECT
Gross Lift vs. Position of Shot Bag
June 17 - 1946   C + 3 - 2C

Graph 2

-107-

Graph 3

NYU BALLOON PROJECT
Buoyancy Vs. Altitude
2/11/49   LMB   C49-4

Gross Load
vs
Altitude Sensitivity
C49-3
JAN 24,1949   LHM

$A = 31,400/L$ (0-30000 ft)

$A = 21,052/L$ (40,000-105,000 ft)

Load in kg

Altitude Sensitivity (A) ft/kg

Graph 4

Note: On flights made in February, 1949, spring

bow appendix closers were used successfully with

rates of rise exceeding 1000 feet per minute. Of

those described on page 10, this type of appendix

stiffener is now recommended.